Spectacle de la Nature:
OR,
NATURE DISPLAY'D.

BEING

DISCOURSES

On ſuch PARTICULARS of

NATURAL HISTORY

As were thought moſt proper
TO EXCITE the CURIOSITY
AND
FORM the Minds of YOUTH.

Illuſtrated with COPPER PLATES.

VOL. IV.

Tranſlated from the Original *French*.

The THIRD EDITION, Corrected.

LONDON:
Printed for R. FRANCKLIN, in *Covent-Garden*; C. DAVIS, in *Pater-noſter-row*; and J. PEMBERTON, in *Fleet-ſtreet*.
M.DCC.XL.

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TO

Sir HANS SLOANE, *Bar^t.*

PRESIDENT;

AND TO THE

COUNCIL and FELLOWS

OF THE

Royal Society *of* LONDON,

FOR

Improving NATURAL KNOWLEDGE,

THIS

FOURTH VOLUME

OF

Spectacle de la Nature,

Is humbly Dedicated,

By their moſt Obedient Servant,

JOHN BAPTIST DE FREVAL.

A LETTER FROM THE PRIOR TO THE CHEVALIER.

SIR,

YOU deſire me, (and from a good Friend ſuch Deſires are Commands) Firſt, To pick out for you a Set of choice portable Books fit for a Gentleman of the Sword: Secondly, To write down for you, and ſend you the Sequel of our Converſations on the *Spectacle de la Nature*; that Abſence, as you are kindly pleaſed to ſay, may not be a Bar to your Pleaſures. I ſhall readily, and to the beſt of my Power, comply with your Deſires on both theſe Heads. Nor can I, indeed, with any Decency, give a cool Anſwer to ſuch judicious and reaſonable Requeſts; and I ſhall, perhaps, find my own Account, in trying to fill up ſome of your ſpare Hours, when you are not engaged in your Exerciſes and Travels.

A Soldier's Library (eſpecially when he is in Service, or on the Road) neither muſt or can conſiſt of many Volumes. A judicious Choice is the chief Merit of his Books; and theſe may very well be reduced to the three following, *viz. A New Teſtament*, *Cæſar's Commentaries*, and *Euclid*. Nor do I doubt, but you always will join to them the Book of *Nature*, and that of *Mankind*. Such a Library may attend you every where, fill up all the Vacancies, as well as ſupply the Wants, of your Life, and be every Day ſwell'd with new Obſervations, without multiplying your Incumbrances, or magnifying your Baggage. This is all I can do with regard to your firſt Requeſt, and I think it ſufficiently anſwer'd.

As to the Second, *viz*. To proceed in taking a View of the moſt beautiful Parts of Nature. As we have already ſurvey'd the internal and external Parts of the Earth, the very Order of Nature itſelf dictates, that the Heavens, and the Relations, which the ſeveral Parts of the Univerſe have to our Wants, ſhould be the Matter of our following Diſcourſe.

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Spectacle de la Nature.

A
PLAN
OF THE
STUDY of the HEAVENS.

DIALOGUE I.

Part I. of Spect.^{e} de la Nat. Vol. 1.

WHEN heretofore we examined, merely by way of Amuſement, the ſeveral Operations of little Animals, and the Structure and Frame of the ſmalleſt Plants, you remember, Sir, that you therein diſcover'd a Generation ſo regular, ſo conſtant and perſevering an Uniformity of Species, and an Organization ſo far ſuperior to our limited Underſtandings, that we both were ſtruck with Amazement at contemplating the unfathomable Wiſdom, which the Creator has diſplay'd in the minuteſt and leſs perceptible Objects. Theſe Particulars of Natural Hiſtory ſeem'd to me to have had another good Effect on you, and to have made you inquiſitive.

Part II. Vol. 2. and 3.

The View we afterwards took of the Helps we every-where find near at Hand, on the Surface, as well as within the Bowels of the Earth, made us ſenſible of the Dignity of Man. This Inventory of our Poſſeſſions and Furniture of all kinds, raiſed in us a Surprize, at ſeeing ourſelves ſo very dear to the Creator, and fill'd us with a thorough Senſe of Gratitude, for the Bounties he thus heaps upon us, and diſpenſes to none but us; ſince we are the only Beings he lets into the Knowledge of their Exiſtence, and to whom he has given the free Uſe of the ſame.

Part. III. Vol. 4.

If we caſt our Eyes from the Earth to the Heavens, there we diſcover Beauties of quite another Character. There do we receive Preſents of far greater Value than all that have been mention'd. But though the ſhining Statelineſs of the Firmament makes it the brighteſt Part of the whole Scene of Nature; yet are we much leſs affected and concern'd at the Sight of ſo many magnificent Decorations rolling over our Heads, than we are at the Thought that they all move for our Sake. The Earth, indeed, when compared with that immenſe Globe of Fire that gives it Light, ſeems not to be diſtinguiſh'd from the five or ſix other Planets, which, as well as the Earth, borrow their Light therefrom, and appear to be ſo very inconſiderable Objects in Nature. Again, our Globe, compared with the Stars, dwindles down to an imperceptible Point. What then ſhall we think of him, who inhabits it? He indeed, ſeems to be quite annihilated. Shall we believe, after this, that the Almighty had him in View, when he framed his Works; and that it is for him God has regulated the annual Circle, the Inequality of Nights and Days, and the Viciſſitude of Seaſons?

Sure, the Excellency of the Beings God has created is not to be meaſured with a Fathom. The Inhabitant of the Earth has received an Underſtanding, a Faculty to will, a Soul. It is this minute Being, whom God admits to the Knowledge of his Works, whereas he denies the ſame to the Sun itſelf. It is for Man he deſigns both the Uſe and the Benefit of this ſtately Retinue. Man is the only Creature on Earth, whom God invites to praiſe him for it.

No doubt, Man may very profitably be ſenſible of his own Inconſiderableneſs. But he is the more ſurprized, and the more thankful, when he ſees, with how great Diſtinction God has been pleaſed to treat him, and to make him here below the ſole Spectator, and the true Enjoyer of Nature. Pſal. viii. ver. 5. 6. Far, then, from conſidering his own Meanneſs with a ſtupid Diſcontent, he, on the contrary, is ſenſible, that this his very Meanneſs is advanced by a Deſtination equally noble and gratuitous. He cannot hearken to Reaſon, and not diſcern that pleaſing inchanting Truth; that he is, on Earth, the chief Object of his Creator's Complacency and Concern. Though there were in other Spheres Millions of intelligent Beings, on whom God ſhould think fit to beſtow ſome other Favours, (a needleſs Inquiry, and not within our Reach) would it be leſs true, that Man on all Sides experiences a gracious bountiful Hand, paternal Cares, and an Order eſtabliſh'd only for his Sake? O what Dignity! What a Greatneſs it is, to have a Father, who, on our account, ſtrews the whole Earth with Bleſſings of all kinds, and even vouchſafes to make the very Heavens ſubſervient to our Intereſts!

I need not, my dear Chevalier, here inſiſt on the Excellency of the Study of the Heavens, in order to raiſe your Curioſity that way. That Science, which buſies itſelf about the Order and Courſe of the Stars, the Path and Effects of Light, and all the Relations the Earth can have with whatever ſurrounds it, in ſhort, univerſal Phyſics, is, undeniably, of all Sciences that, which moſt elevates the Soul of Man, by the Grandeur of the Objects it offers to his Conſideration. It may be properly ſaid to enlarge his Mind, in ſubmitting the very Courſe of the Stars to his Underſtanding, and to join with the Merit of doing Mankind many ſignal Services, that of affording Piety, Motives both of a lively Gratitude, and of the moſt profound Veneration.

You very well gueſs at all the Beauty of Aſtronomy, and of the whole Tenor of natural Philoſophy. But I muſt not hide from you, that theſe very Sciences, by the falſe Methods, with which they have been purſued, and the wrong Uſe they have been put to, have been the Occaſion of infinite Miſchiefs. They gave Birth to Idolatry, and have fill'd the World with Prejudices, Superſtitions, and idle Fancies. Nay, Irreligion itſelf has more than once attempted to ſupport itſelf thereon. I therefore ſtop ſhort at the Conſideration, and heſitate on the Choice I am about to make for you; ſeeing the Advantages to be reap'd from theſe Studies are attended with ſo great a Number of Errors and Dangers.

Another Obſtacle not much leſs perlexing is, the Difficulty of letting you into the Celeſtial Motions. It is not with this Part of Nature, as with an Inſect, or a fine Flower, the Knowledge whereof may be attain'd at firſt Sight, or by the Help of a magnifying Glaſs. I therefore thought the eaſieſt and ſureſt Method for me was this; *viz.* To facilitate the Approach of theſe ſo numerous and ſo vaſt Bodies, by offering them to your Sight under different Aſpects, and at ſeveral Times, gradually making them eaſy and familiar to you. Muſt I then begin with requiring of you a large Stock of Machines and Geometry? No ſure; we need not uſe *Greek* or *Algebraic* Terms, ſo long as we can underſtand one another in our uſual Speech.

Part I. of Vol. 4.

I ſhall begin with plainly laying before you, without any Diſputes or mathematical Diſtinctions, what our Eyes, and the firſt Appearances diſcover to us of the Structure of the World, and what common Senſe hints to us of the Excellency of God's Favours towards us, together with the Uſefulneſs of the Day, and of the Celeſtial Revolutions.

Part II. of Vol. 4.

After this, we ſhall go one Step forwarder. As the Knowledge of the Heavens cannot be attain'd but by a long Series of Obſervations, nothing can be more natural than to add to our own Experience that of Men, who lived before us. I am, therefore, to furniſh you with a Hiſtory of the Progreſs, which the ſeveral Obſervers of Nature have made therein from one Age to another. But their Works are of two Kinds; they ſometimes run upon experimental Truths, ſometimes on Hypotheſes; by which they endeavour to explain the inward Frame and Structure of each particular Body, or the general Fabric of the Univerſe, or the Concurrence of thoſe Forces, which put whole Nature in Motion. Do not let us confound the Hiſtory of the Diſcoveries with the Recital of the Hypotheſes. We ſhall, firſt of all, take in hand the Hiſtory of Phyſics, or Experimental Philoſophy, and of the Uſes we have experienced from it. The firſt Naturaliſts, whoſe Diſcoveries I ſhall give you an Account of, were, perhaps, neither great Geometricians or great Calculiſts. They were very often Plough-men, Gardeners, Shepherds, Travellers, or Merchants, who acquainted other People with uſeful Novelties. But what they have taught us is certain, and the Benefit of it inconteſted. It is but juſt we ſhould particularly inſiſt on this Experimental Philoſophy, which makes up the Happineſs of Mankind. Hence we ſhall paſs on to the Hiſtory of general Phyſics, which aims at no leſs than informing us of the Manner, in which every Thing had its Original, or at leaſt at determining the Laws and moving Forces that regulate the Courſe of every Globe. In this we ſhall find many very great Names, and famous Diſputes. From the Expoſition of the Hypotheſes, you will judge of the Benefit that is to be expected from, and of the Value that is to be ſet upon them. In both Hiſtories, we ſhall carefully remark the wrong Uſes, to which theſe Sciences have been applied, and prevent the Miſtakes and Extravagancies, of which this Study might be the Occaſion.

You are ſenſible, my dear Friend, that when I choſe this Method, rather than to lead you from the Geometrical Theory of the World, and from the Study of the Motion of the Celeſtial Bodies, to the Conſideration of particular Effects, it was in order to render eaſy to you the nobleſt of all Studies, inſtead of giving you a Diſguſt to it, by regularly purſuing it with Prolegomena, Axioms, and Mathematical Demonſtrations.

This Choice of mine is ſtill grounded on the Deſire I have of procuring you another far greater Advantage. Your chief Intereſt, as well as mine, is perfectly to know the Place we inhabit, and the Preſents we have therein received. Let the Utility or Inutility of general

Phyſics be what it will; (and this will plainly appear from the Compariſon we ſhall make between that and the Experimental) the chief Good we ought conſtantly to aim at in both, is, to make the Whole ſubſervient to the Knowledge of the Earth. The Study of the ſeveral Points, Motions, and Aſpects of the Heavens, is not intended to acquaint us with what paſſes in the Firmament; and we in vain are inquiſitive that way, unleſs it be to improve our Manners and our Conduct within our own Sphere. But if the Study of the Heavens may be made to refer to us, and have a general Relation to Mankind, it muſt chiefly be effected by a faithful Account of thoſe Obſervations, which Neceſſity has from time to time cauſed People to make on the ſeveral Objects Heaven offers to our View, and of the conſtant Benefits, which Mankind knows how to reap therefrom. The Hiſtory of Natural Philoſophy is indeed the Enumeration of our Wants, and of thoſe plentiful Helps God has placed within our Reach to ſupply them. It is good only as it ſhews us what is over our Heads, without making us loſe Sight of what is under our Feet, and as it engages us to ſerve our Brethren, (that is, all Men without Exception) by a more perfect Knowledge of that Soil we are appointed in common to improve.

I ſhall therefore endeavour, my dear Chevalier, to lay the Hiſtory of Natural Philoſophy in ſuch Order before your Eyes, that after having read it, you may have a tolerable Idea of the general Diſpoſition of our Globe, of the Aſpects, under which the Heaven is ſeen by the ſeveral Climates of the Earth, and of the principal Intereſts, which unite the Inhabitants thereof. In this Science, more than in any other, I ſhould think myſelf to have led you the beſt Way, could I have taught you to leave, without Regret, whatever is metaphyſical, abſtruſe, and no ways relating to Man's Wants; how to make your ſelf Maſter of what is certain, practical, and of general Acceptation, of what has a Relation to Objects under our own Management, and of what may contribute to our Happineſs, either by keeping us more conſtantly buſied, or chiefly by rendering us more virtuous.

The Subject of the fifth Volume.

For the ſame Purpoſe, I ſhall, perhaps, from the Hiſtory of Natural Philoſophy, paſs on to the practical Part thereof; and if you ſeem to like theſe Subjects, and to be deſirous of acquiring a more exact and more particular Knowledge of the Uſe of Globes, of Aſtronomical and Optical Inſtruments, of the Manner, in which we calculate the Years, Months, Lunations, and the whole Order of our Days, of the ſeveral Uſes we may experience from the Knowledge of Motion, of the Laws of Gravity, of the Spring of the Air and Atmoſphere, of the reciprocal Preſſures of Fluids, and of the Application of the moving Forces to our ſeveral Neceſſities; in order to ſatisfy you on all theſe practical Points, we ſhall, perhaps, in our following Converſations, have recourſe to a few mechanical and geometrical, but, at the ſame time, ſo plain and ſo fruitful, Principles, that you will be ſurpriſed at ſeeing, that the experimental Knowledge of Nature, which is the moſt engaging and moſt pleaſing of Sciences in all reſpects, and the moſt proper to ſatisfy any judicious Mind, both by the Uſefulneſs and Variety of its Productions, is at the ſame time the eaſieſt to be arrived at, and yet the leaſt cultivated.

The whole Purport of my Plan is, in a ſmall Compaſs, to join together whatever is certain and uſeful in natural Knowledge; Firſt, By the Help of our Senſes, and by inſpecting Nature; Secondly, By Help of the Hiſtory of what has been from Age to Age diſcover'd or improved; Thirdly and laſtly, By the Help of ſome of the Elements of the plaineſt Geometry.

Let us begin the Study of the Heavens by the plain Teſtimony of our Eyes. The Courſe and Method of it being pretty much in our Choice, we ſhall begin by the Night, which darkens every Thing, and then run over what the Day ſhall ſucceſſively unveil to our Eyes.

THE NIGHT.

DIALOGUE II.

THE Night is no Being. It is barely the Interruption of the Motion of Light towards our Eyes. But even Nonentity itſelf is not unfruitful in God's Hands; and as he has made all Beings ſpring out of nothing, he every Day fetches from it, not indeed any new Beings, but wholeſome Inſtructions, and many regular Utilities, in Favour of Man.

The Night affords us Inſtruction.

The Night, by taking from us the Sight and Uſe of Nature, in a manner re-calls us to that primitive Nothingneſs from whence we firſt ſprung, or puts us again in that State of Darkneſs and Imperfection, that preceded the Creation of Light. The Diſtemper, which weakens our Bodies, makes us the more ſenſible of the Value of Health; and the Night, which in ſome ſort annihilates the whole Univerſe, with regard to us, makes us the more ſenſible of the ineſtimable Price of Day-light. But Night is not only deſign'd to ſet off by its Shades the Beauties of the great Picture of the World, and to inſpire us with a greater Humility at the Sight of that Darkneſs, which is natural to us, or with a livelier Senſe of Gratitude at the Return of a Light, which is none of our Due. Though the Inſtructions it affords us were never ſo uſeful, yet would it be a ſad Thing, ſhould it impoveriſh us merely for our Improvement. What Night ſeems to reſcind from our Life, by daily depriving us for ſeveral Hours together of the Uſe of Light, and of the Sight of the Univerſe, it abundantly makes that up to us, by the Reſt it then procures.

The Neceſſity of reſting.

Man was born to labour. Such is his Vocation and Eſtate. But he cannot undergo his Toil, unleſs his Blood ſupplies him continually with an infinitely ſubtle and active Matter, which ſets the Springs of the Brain, and the ſeveral Muſcles of the Body to work. But the perpetual Waſte, which is made of that Matter, which with ſuch Swiftneſs anſwers all his Purpoſes, would at laſt throw him into a lingering and conſumptive Condition, did he not recruit himſelf, and make up his Loſſes, by the Uſe of new Aliments; and theſe, again, could neither be digeſted, or regularly diſtributed through the whole Body, was he always in Motion. He muſt leave off the Work of his Brain, his Hands or his Feet; that the Heat and Spirits, which exhaled from him, may be ſolely employ'd in aſſiſting the Functions of the Stomach, during the Inaction of the other Parts of the Body.

But God did not leave the Uſe and Diſpoſal of that Reſt to the Reaſon and Management of Man. He himſelf takes care to lull him aſleep. He makes Sleeping an agreeable Neceſſity to him, without either letting him into the Knowledge, or giving him the Government thereof. Sleep is an incomprehenſible State, of which Man is ſo far from conceiving the Nature, that he can by no means either procure it to himſelf when it comes not of its own accord, or refuſe it when it ſeizes upon him. God has reſerved to himſelf the Diſpenſation of that Repoſe, the Time and Meaſure of which, he knew, would never be well regulated by human Reaſon. He has choſen Night as the propereſt Time, and the beſt Means to introduce Repoſe into the World, and to fix the Duration of it.

Night, indeed, in covering all Objects with Darkneſs, obliges Man to ceaſe from his Works; and in order to refreſh him after all his Fatigues, by keeping him unactive, it removes whatever might agitate him too much, or affect him too ſtrongly. It conveys Silence and Darkneſs every where. It takes from him the Scene of Nature, in order to ſtrip him of the Uſe of his Senſes; and as the one is of no Uſe without the other, it at once deprives him of both. Who cannot diſcern, in this great Regard of Providence for Man, the Cares of a tender Mother, who removes all Noiſe from the Place where ſhe has laid her Son? She fondly watches over him, in order to ſecure his Repoſe.

Night and Sleeping are ſo connected, and the former ſo properly made to bring on the latter, that whenever we ſtand in need of Repoſe, we begin it by procuring a ſort of artificial Night to ourſelves. We ſeek to ſome ſhady loneſome Place, and have recourſe to Curtains and Window-ſhutters. Our Senſes are never unbent but by the Removal of what gives them Agitation; and it is evidently this Service, to which Night is commiſſion'd and appointed. But let us conſider for a Moment, with what a diſcreet Caution it diſcharges that Duty.

The Uſefulneſs of the gradual coming on of Night.

Night, in ſerving Man, does not tie him up exactly to any preciſe Moment. It comes not in a blunt and abrupt Manner to extinguiſh the Light of the Day, and all on a ſudden to rob us of the Sight of thoſe Objects we are intent upon. Far, indeed, from coming upon us unawares in the midſt of our Works or Travels; it advances on the contrary by ſlow Steps, and only increaſes and thickens its Darkneſs by degrees. It permits us to make an End of what it is our Intereſt to finiſh, and does not precipitately deny us the Sight of the Goal we ſtrive to arrive at. It is not till after it has decently told us of the Neceſſity of taking our Reſt, that it finally makes an End of darkening the whole Face of Nature.

During all the Time of Man's Repoſe, Night, for his ſake, huſhes every Noiſe, keeps off all glaring Lights, and whatever might too ſtrongly affect him. It, indeed, ſuffers a few Animals, whoſe grim Aſpect might ſcare him while he is at work, to go forth under favour of its Darkneſs, and ſilently ſeek their Food in the abandon'd Fields. It affords theſe voracious Creatures Means of coming to clear his Abode of whatever might infeſt it, and even of taking from him ſuch Things as are by him too careleſsly guarded. It permits, however, the Animal that ſtands Centry by him, to give him Notice of what concerns him, while it impoſes Silence on every other Creature. It keeps the Horſe, the Ox, and all his other Domeſtics faſt aſleep around him. It diſperſes the Birds, and ſends each of them to his reſpective Abode. As it comes on, it gradually huſhes the Winds that diſturb'd the Atmoſphere. It evidently is commiſſion'd to ſecure the Lord of Natures Reſt. It cauſes his Repoſe to be reverenced every-where, the Moment of which is no ſooner come, but all Tumult ceaſes; all Creatures retire, and for ſeveral Hours together an univerſal Silence reigns throughout his Habitation.

Nor does, for all that, Nature's Palace remain wholly void of Light. For as thoſe, who inhabit therein, might perchance be inclined to prolong their Works or Journies during the Night itſelf; ſeveral Flambeaux ſcatter'd in the Firmament ſtill guide their Steps. But theſe Lights, which were granted in order not to leave them in a total Darkneſs, yield but a gentle, and not a very brilliant Light. It would have been neither proper or juſt, to ſupply thoſe that wake with ſuch a Light as might interrupt the Repoſe of others.

When the Abſence of the Moon, or the Thickneſs of the Air, takes from us the Light we ſtand in need of, we are always Maſters of procuring it to ourſelves. We find the Principle of it in the Bowels of Flints, and its Fewel in the Wood, the Oil, the Fat of Animals, the Wax, which Bees collect from Flowers, and in the vegetative Tallow that may be fetch'd from ſeveral Plants *. But the nocturnal Light ſerves us very differently from that of the Sun. The latter enlivens us, it warms us, it

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* They make in Britaigne a green Wax-candle with fat and thick Juices expreſs'd from ſeveral Plants. There are found, in the Iſland of Ceylon, large Foreſts of Cinnamon-trees, whoſe thin Bark, and eſpecially that of the Branches, is that ſweet ſmelling Spice ſo well known by the Name of Cinnamon, and whoſe Fruit, when ſtrain'd, yields a greeniſh ſort of Tallow, which is whiten'd, and herewith they make Wax-candles. They find, in ſeveral Places of Miſſiſſipi, the Tree call'd Cirier; the Seed of which they throw into boiling Water, in order to extract a ſort of Oil that ſwims above it. They skim it off, and let it thicken in Cakes, in order to make Wax-candles of it.

it preſſes us, it ſends us to work. On the contrary, the Fire we light does not come of its own accord, but ſtays for our Orders. Nay, we cannot come at it without ſome Endeavour, or keep it without Care. That borrow'd Light is always ready to vaniſh; it ſeems to be miſplaced, and even loth to diſturb the Repoſe of Nature. Man rids himſelf of this, ſo ſoon as it becomes either troubleſome or uſeleſs to him, and he of neceſſity wraps himſelf again in that beneficial Darkneſs, that helps him to recruit his Spirits, and recover his Strength with Sleep.

It is not only by its Darkneſs that Night becomes uſeful to us. It is again of Service through a Coolneſs, which, by every where preſſing down the Spring of the Air, makes it capable of working with greater Activity in all Bodies, and of communicating a new Vigour, both to the dry Graſs, and to the infeebled Animals. It is in order to preſerve this beneficial Cool, that the Moon, in reflecting to us the Light of the Sun, gives it us in ſuch a Degree as has no ſenſible Heat. In vain would we collect that Light in the Focus of the ſtrongeſt Burning-glaſs. It does not even affect the Thermometer when put in the Point that unites its Rays, nor cauſes there the leaſt Dilatation in the Spirit of Wine, otherwiſe ſo ſuſceptible of it. An admirable Caution of the Divine Artificer, who has eſtabliſh'd the Order of the Night, and foreſeen whatever would be beneficial in it. He reſerves for that Time a Light ſtrong enough to remove Darkneſs, but at the ſame time too weak to alter the Coolneſs of the Air. He alone knows his own Works, and alone can know the immenſe Degree of Diminution of a Bundle of Rays, which he cauſes to paſs from the Body of the Sun to that of the Moon, and the Remainder whereof are reflected down to us weak, and quite deſtitute of Heat. It is perfectly needleſs for us, to determine that Degree by Experiments, and long Calculations. It would be ſo much Philoſophy loſt, on Account both of its little Uſe, and great Uncertainty. But it is no leſs eaſy than it is important for us to diſcern and praiſe the infinite Wiſdom, that did ſo well proportion all theſe Cautions to our Wants.

The Cool of the Night.

The Spectacle of the Night.

When Man is inclined to have the Benefit of the faint Light, or of the wholeſome Coolneſs, which attends the Return of Night; he, it is true, ſees no more the ſame Beauties in his Habitation, and every Thing is leſs ſtriking and lively there. But as the Day has afforded him its proper Spectacle, the Night, in its turn, favours him with another, that has Charms peculiar to itſelf, and of quite another Character.

The Beauty and Uſefulneſs of the Stars.

We cannot doubt, but that thoſe immenſe Globes of Fire, which enlighten our Night at ſo great a Diſtance, have each of them in particular a peculiar Appointment, which anſwers in God's Purpoſes the Magnificence of their Appearance. Sure, the Reaſons and Frame of theſe wonderful Works, about which the Creature has once employ'd himſelf, will greatly deſerve, that we ourſelves ſhould be taken up with them in that Life, after which we all of us ſo ardently aſpire. But who ſhall preſume to explain what the Almighty keeps in the profoundeſt Secrecy? Who ſhall dare to anticipate what he has reſerved for another Oeconomy? The ſmall Glimpſe, which a few Genius's more attentive than others are by him permitted to have of thoſe Objects, being perfectly unintelligible, and, as it were, unknown to the reſt of Mankind; it is not in the particular Deſtination of each individual Star, nor in the general Harmony of theſe Spheres, that we are to look for the Means of inſtructing Man, or for the Way of regulating his Duties, and the Affection of his Heart. The prevailing Motives, which inſpire him with Love, and incite him to Praiſe, muſt be drawn from what he ſees, from what concerns him, and from what is evidently ſubſervient to him. Now, what the Almighty has been pleaſed to reveal to him of the Order of the Heavens and the Stars, extends no farther than the Aſpects, under which he ſhews them to him, and the Uſe he allows him to make of them. But yet the little he vouchſafes to communicate to Man is full enough for him, and Matter ſufficient for the moſt profound Admiration. God has ſo fitly placed the Habitation of Man, with regard to theſe immenſe Globes, that from that Situation there reſults an Order, which he alone enjoys, a Beauty which, inchants his Eyes, and a Regularity that makes up the Happineſs of his Life.

Theſe innumerable Fires, firſt, become, through this wonderful Diſpoſition, with regard to him, ſo many thouſand ſparkling Luſtres hung up in the magnificent Cieling that covers his Abode. He ſees them ſhine and glitter on every Side, and the dark Azure, that ſerves them as a Ground, ſtill heightens their Brightneſs and Splendor. But their Influences are gentle; their Rays are diſperſed through Spaces ſo vaſt and immenſe, that they are entirely blunt and deſtitute of Heat, by the time they arrive at Man's Abode. Thus by the Creator's Providence he enjoys the Sight of a Multitude of fiery Globes, without any Risk, either to the Coolneſs of his Night, or the Quiet of his Repoſe.

The Stars that are near the Pole.

But it is not ſolely to adorn his Palace with coſtly Gildings and a delightful Variety, that God every Day makes this magnificent Arch, with all its Decorations, turn around him; Man reaps, beſides, many conſiderable Benefits therefrom. Among the Stars, which he can eaſily diſtinguiſh, he knows ſome that are always over his Head, and conſtantly retain the ſame Place in the Firmament, without ever deviating from it. He ſees others that deſcribe very large Circles, and riſe gradually above his Horizon, and then diſappear, ſetting beneath the Extremities of the Earth, which terminate his Sight. The firſt rule his Voyages both by Land and Sea, by ſhewing him in the Dark one Side of the Heaven, the Aſpect whereof remains conſtantly the ſame, and is enough to keep him from going out of his Way. But as the Clouds, and the Thickneſs of the Air, may on occaſions deprive Man of the Sight of thoſe Stars that were given him as his Guides; God has put ſuch an intimate Relation between that Part of the Heaven, and the Iron, which has been touch'd with the Load-ſtone, that whenever that Iron is placed in Equilibrio, it inceſſantly turns one of its Ends, and that always the ſame, towards the Pole. By this means, the Traveller is inform'd of the Place where thoſe Guides, then not viſible, remain, and his Way is always

The Sea-Compaſs.

always direct and regular, notwithſtanding the accidental Diſorders of the Atmoſphere.

The other Stars.

The other Stars vary their Aſpects; and though they always keep the ſame Situation among themſelves, they nevertheleſs, with regard to us, daily change the Order of their Riſing and Setting. Theſe very Variations, by their Regularity, fix the Order of our Works, and by a few ſettled Points determine the Return and the Concluſion of Seaſons. Heat and Cold alone would have been too uncertain, and ſubject to too many fatal Revolutions, had they been made the Rule of Seed-time, and the Culture of Lands, or to diſtinguiſh what Times were proper for Navigation. Man finds all neceſſary Inſtructions on theſe Accounts, when he ſees the Sun paſs under a Series of different Stars, and yearly make the ſame Way in an uniform Manner. Thus it is that he knows the Courſe of that moſt beautiful Star. He aſſigns a Name to every one of the Houſes, by which it paſſes in its Way. He knows the exact Duration of its Stay in each Houſe. He likewiſe is acquainted with the Abodes of the Moon and Planets, with the Limits of their Courſe, and with the whole Oeconomy of the Months and the Year. He repreſents them in a ſmall Compaſs with Machines, whoſe Revolutions are exact and regular. He from one End of the Heaven to the other obſerves ſeveral Points, Lines, Figures, and certain Marks that guide him in his Operations, and in the exact Diviſions he is obliged to make of the Surface of the Land and Water. Thus is he acquainted with the whole Firmament; he delineates the Map of it, and very properly may be ſaid to make a Voyage thither. But all theſe Objects, which he ſo uſefully there diſtinguiſhes, dwindle and diſappear at the Approach of the Sun. And if he diſtinctly determines which Stars are ſucceſſively eclipſed by its Rays, it is from the Knowledge he has of their Remoteneſs, or Diſtance from thoſe, which Night diſcovers to him. It is then Night, which, together with a new Scene, gives Man the ſureſt Methods of ruling the Works and Order of Mankind.

Night is not confined to the Brightneſs of the Stars. It has other Fires that ſtill enlighten Darkneſs much better, and form therein Pictures of quite a new Character. The Moon, above all, draws out of Obſcurity the Objects that are neareſt to us, and colours them in ſuch a Manner, as agreeably changes their whole Appearance. The Moon then itſelf is the moſt beautiful Object in Nature. It pleaſes the Eyes by the Softneſs of its Splendor, and varies the Scene in daily changing its own Figure. It every Day puts the Place of its Riſing back from the *Eaſt* to the *Weſt*. Sometimes it puts on an aſh-colour'd Garment, almoſt entirely border'd with a plain golden Rim. Sometimes it dreſſes in Purple, and comes above the Horizon with a Shape much larger than ordinary. It leſſens afterwards, and whitens as it aſcends. It becomes brighter and more ſerviceable, as Day-light leaves us; and both when it but partly ſhews itſelf, and when it appears at full, it every where conveys new Ornaments in Nature, by ſuddenly breaking out, and ſucceſſively ſinking again among the Clouds; ſometimes by caſting its Beams through a Thicket of leafy Branches; ſometimes in decking itſelf with a Border of many Colours it borrows from the Clouds, or in attracting the Eyes of all the World, when the Earth, being placed between the Sun and the Moon, caſts its Shadow upon the latter, and ſeems by degrees to gain upon it, or totally to overſpread it with Darkneſs.

Sometimes the Planet *Mercury*, and oftner *Venus*, appear, with regard to us, to diſcharge the Functions of the abſent Moon; ſo bright is their Splendor, either at the Beginning of Night, or at the Break of Day. All theſe Lights, as well that, which rules the Night, as the others, which attend it, are moſt delightfully multiplied by Reflexion in the perfect Glaſs of Fountains and Rivers.

The Summer Nights.

But if Night becomes fine and delicious, it chiefly does ſo, when the ſultry Heats of the Summer render the Day troubleſome. It then makes Man reliſh all the Comforts that can make him amends; it joins together with long Twilights the Preſume of Gardens and Meadows, and the gentle Coolneſs of the Air. It offends his Eyes, much leſs than it amuſes them, with a thouſand little Fires that break through the Vapours of the Earth, with Lightnings that ſlightly enflame the Edges of the Clouds, or with the Beams of the Boreal-fire, wherewith it very often graces the Northern Part of the Hemiſphere; at leaſt it makes them leap and flutter from one End of the Horizon to the other.

See Vol. 3. page 191.

Sometimes the Earth, like the Firmament, ſeems all ſtrew'd with Stars. The female Glow-worms, that kept under Ground during the Day, then come out to enjoy the Air, and then the Fields ſparkle with new Fires. They are deſtitute of Wings to help them to look out for Company; but they are more ſparkling than Diamonds, and their natural Brightneſs cauſes them to be ſeen in the Dark * by the Males, who have received Wings to come to them, but have not, like them, the Prerogative of Beauty.

Here, my dear Chevalier, methinks I hear you murmur; very likely you reproach me with leaving the Heavens, again to crawl upon Earth, whither the Brightneſs of thoſe Inſects had recall'd me; but we have actually done with, and ſhall no longer dwell upon, them. Let us return to our celeſtial Fires, and eſpecially to the magnificent Light, whoſe Splendor is ſo much ſuperiour to that of others. The ſurpriſing Variety of the Aſpects of that Planet, while the others ſeem to be conſtantly the ſame, raiſes a thouſand Queſtions in the Spectator's Mind, and gives Birth to many particular Reflexions.

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* The Chevalier Valliſneri, in his Work intitled, Saggio d'Iſtoria Naturale, Vol. 2. Edit. fol. Pag. 419, recounts, That one of his Friends having in his Hand a Glow-worm without Wings, another that had Wings, but was not relucent, came into his Hand to meet the firſt, which was the Female. There are ſeveral Sorts of Glow-worms, and ſhining Beetles; eſpecially in America. There is one that wears a Sort of Lantern upon his Head.

THE

THE MOON.

DIALOGUE III.

A Very ſew Days ago, the Moon appear'd under the Form of a Creſcent, a little before the Dawn of Day. Now I ſee it under the ſame Form at the Approach of Night, with this Difference only, that, in the Morning, its Extremities or Horns look'd towards the *Weſt*, whereas the Horns of yonder Half-moon are extended and point towards the *Eaſt*. Three Days now are paſs'd ſince the Moon has not ſhew'd itſelf, either at the Approach of the Sun, or after its ſetting; What then was become of it? Whither did it retire? What was it that ſcreen'd its Light from us? Had any one put out its Light? What Agent in Nature has the Charge of rekindling that Lamp, and of returning it to us in ſo regular a Manner? Why will this luminous Creſcent, in four or five Days time, ſo far widen as to ſhew us the quarter Part of a Sphere? How ſhall this Light, by its ſucceſſive Increaſe, in ſomething leſs than a Fortnight, come to ſhew me a Circle of Light ſomewhat defective on the left Side, and at length a complete and regular Disk or round Figure, perfectly luminous? When the Light begins to appear on the Body of the Moon, it gets up on the Weſtern Side; it gradually ſpreads towards the oppoſite Side; and inſenſibly gains upon the whole Surface. Is it a Fire conſtantly increaſing? But why does that

Light, immediately after the Full-moon, begin to leave that very Side, on which it made its firſt Appearance? It ſhrinks towards the Weſtern Edge of the Moon, and by-and-by will be no more than a narrow Rim. That Rim afterwards dwindles down to a ſmall Thread without Breadth, and at laſt vaniſhes entirely. What can be the Cauſe of ſo inconſtant a Light?

The Cauſe of ſo many Phaſes excites my Curioſity; but I find ſo conſtant a Regularity therein, that I ſhould ſtill be much better pleaſed to know the Purpoſe of ſuch a Work, or the Uſefulneſs of this Oeconomy. I think I can gueſs at the Aim and Cauſe of it; nay, methinks I even perceive them both very diſtinctly, by making uſe of thoſe Phænomena, which are certain, in order afterwards to obtain the Knowledge of what is not ſenſible to my Eyes.

In all the Eclipſes of the Sun, which I have had an opportunity of ſeeing, I remark'd, that they always happen between the laſt Creſcent of one periodical Courſe of the Moon, and the firſt Phaſis of the New, that is, between the Time when the Moon is neareſt to the Sun, and that when it begins to go off from it. All the Spectators, whom the ſudden failing of the Light then drew together in Platoons, ſaw, in an uniform Manner, and ſhew'd me, either in ſtill Water, or through a darken'd Glaſs, a round and perfectly opake Body, which inſenſibly ſlid before the Disk of the Sun, and either partly, or almoſt wholly, intercepted the Light thereof. This dark Body could be no other than that of the Moon, which on the foregoing Days had been obſerved more and more to advance towards the Sun, and is found in one or two Days after to recede from it. The Moon, after having barr'd the Paſſage of that Portion of the ſolar Rays, which directly tended towards our Globe, appear'd of the moſt horrid and the deepeſt Black; whereby I underſtand that it ſhines only as it is lighted. The Side, which it turn'd towards us, being not able to receive any Light from the Sun, had conſequently none to give us. The Moon, therefore, is but a maſſy opake Globe, whoſe Brightneſs is only the Reſult of a borrow'd Light; it beats back towards us, or reflects the Rays that fall on its Surface, and cannot paſs through it. This firſt Truth once known, all the reſt is unveil'd, and by this Help it becomes an eaſy matter to ſee the Order of its Viciſſitudes, and the Reaſon of its Phaſes.

The Motion of the Moon.

At preſent let us not conſider, whether the Earth, by turning on its own Axis before the celeſtial Bodies, ſhews them to us as though they were moving round us, or whether the Heaven, really turning, carries them along with itſelf from Eaſt to Weſt. Let us even ſuppoſe, that this daily Revolution of the Heavens is real, and for the preſent ſtick to what our Eyes ſeem to teſtify on that Head. The Moon, which makes a Part of the whole Maſs of the Heavens, and is thereto fix'd, ſhall of courſe be carried away from Eaſt to Weſt. We ſhall ſee it riſe, aſcend, go down, and at laſt retire into that Half of the Heaven, which the Horizon hides from us. But from the Manner, in which it approaches to, and afterwards goes from the Sun, retiring always towards the Eaſt, we are convinced that it has a Motion peculiar to itſelf, whereby it advances in a Way contrary to that of the Heavens. While a Ship is moving from Eaſt to Weſt, with the Stream of the River, the Sailor, who is borne away by the Ship, does nevertheleſs freely walk from the Prow to the Stern, and from Weſt to Eaſt. A Fly placed on the Wheel, that lifts a Weight, is carried downwards from above by the Motion of the Wheel, but ſhe can by her own Motion, gradually advance the contrary Way upwards from below.

Every thing confirms us in the Notion, that the Moon has a peculiar Motion of its own, whereby it turns round the Earth from Weſt to Eaſt. After it has been between us and the Sun, and then has retired from under that Star, it continues to retire ſtill towards the Eaſt, and daily to change the Point of its riſing. In a Fortnight's Time it will have reach'd the moſt eaſtern Part of the Horizon, when the Sun ſhall be obſerved to ſet; it is then in Oppoſition to that Star. In the Evening after the Sun is retired, it aſcends our Horizon, and ſets in the Morning very near the Time of Sun-riſing. If then it proceeds in making the Circle it has begun round the Earth, half of which is already finiſh'd, it ſhall viſibly go from its Point of Oppoſition to the Sun. By little and little it ſhall appear leſs remote from it, and conſequently be ſeen later than when it of its

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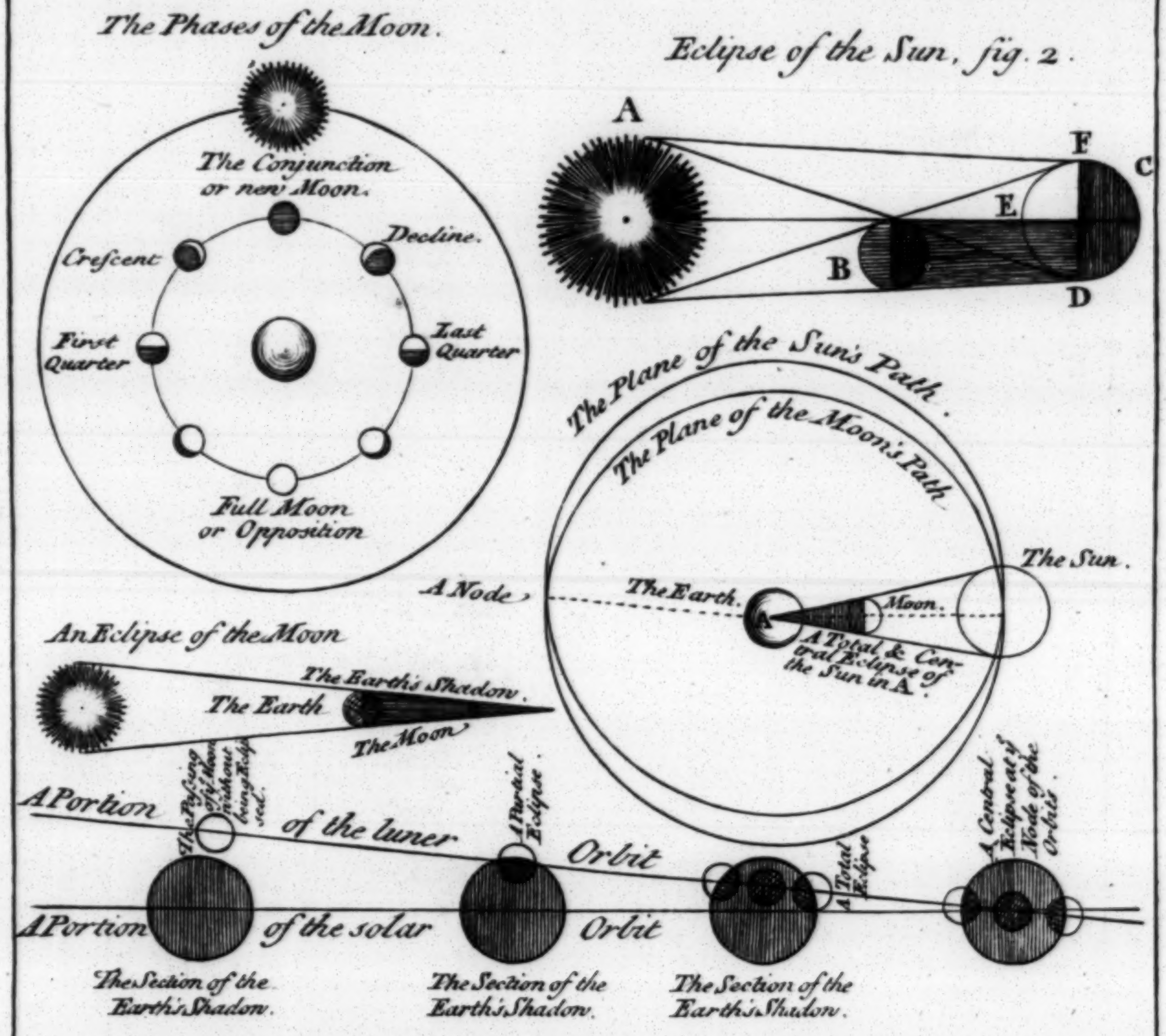
The Phases of the Moon.
The Conjunction or new Moon.
Crescent
Decline.
First Quarter
Last Quarter
Full Moon or Opposition
Eclipse of the Sun, fig. 2.
A
B
C
D
E
F
The Plane of the Sun's Path.
The Plane of the Moon's Path
The Sun.
A Node
The Earth.
Moon.
A
A Total & Central Eclipse of the Sun in A.
An Eclipse of the Moon
The Earth's Shadow.
The Earth
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A Portion of the luner Orbit
A Portion of the solar Orbit
The Passing of ye Moon without being Eclipsed.
A Partial Eclipse.
A Total Eclipse
A Central Eclipse at ye Node of the Orbits.
The Section of the Earth's Shadow.
The Section of the Earth's Shadow.
The Section of the Earth's Shadow.

In the Figure, 2. **A** *is the Sun.* **B** *the Moon.* **C** *the Earth. The Solar Eclipse is Total in* **D**. *The people at* **E** *see half of the Sun. Those at* **F** *have no Eclipse.*

Ja. Mynde Sculp.

was in Oppoſition; and it ſhall at laſt draw ſo near that Star, that it ſhall not be viſible till a little before the riſing of the Sun.

Its Phaſes.

If the perpetual Viciſſitude and progreſſive Retardings of the Moon, are an evident Conſequence of its Motion, the Variety of its Phaſes is a no leſs ſenſible Conſequence of the ſame. No one is ignorant, that a Globe enlighten'd by the Sun, or by any other luminous Body, can receive the immediate Light thereof on only one of its Halves. The Light glances on the Extremities that terminate the enlighten'd Half. It continues its Way directly through the Air, without inclining towards the oppoſite Half, which of Neceſſity muſt remain darken'd. When then the Globe of the Moon was in Conjunction, that is, between the Sun and us, it had its whole enlighten'd Half towards the former, and the whole darken'd Half towards us; thus was it inviſible, though not annihilated; ſince no Object can be ſeen but by the Rays of Light that are reflected from it. But if the Moon has retired from under the Sun, and is withdrawn fifteen or twenty Degrees eaſtwards, then it is no longer the whole darken'd Half, which is turn'd towards us. A ſmall Portion or Edge of the enlighten'd Half begins then to look towards us. We therefore ſhall ſee this luminous Edge on the right Side towards the Sun when but juſt ſet, or even before it ſets, and the Extremities or Points of that Creſcent ſhall be to the left, or looking eaſtward. When afterwards it is got to the quarter Part of its Courſe round the Earth, it gradually turns towards us its enlighten'd Part, and ſhews us one Half of it. Now the enlighten'd Part of the Moon is exactly one Half of the ſame. The Half of that Half can then be no more than one quarter Part of the whole Globe; and that Quarter it is, which we in reality ſee. As the Moon retires from the Sun, and the Earth is nearly between them both, the Light covers a greater Space in that Part of the Moon, which looks towards us. When, at laſt, the Oppoſition ſhall become entire, and our Globe ſhall be directly, or almoſt directly, between the Sun and the Moon, the Light ſhall ſpread from one Border to the other, and the Half turn'd towards us ſhall be no other than the enlighten'd one. But the very next Day the enlighten'd Half ſhall begin to get a little behind the Moon, with regard to us; the Half it turns towards us ſhall not then be exactly and entirely viſible. The Light ſhall gradually leave the weſtern Part, and in the ſame Proportion extend itſelf to the Half that looks from the Earth, and the Extremities of the luminous Half ſhall ſucceſſively paſs over the whole anterior Disk on the left; till the Moon being again about to paſs between the Sun and the Earth, ſhews, at laſt, to her, no more than a ſmall Border of that enlighten'd Half that is turn'd from our Eyes; and the Sun appearing in this Circumſtance a little on the left-hand-part of the Moon, with regard to the Spectator, the Creſcent or Border of Light muſt needs ſtretch forth it's Horns on the Right, or towards the Weſt.

This Theory is ſelf-evident; but ſhould it require any new Proofs, they may be found in the Explication of the Particulars not yet examined.

We have very often ſeen the Moon in an Eclipſe, and cannot but have remark'd, that it never is ſo, but when it is in Oppoſition, that is, at the Full. This Phænomenon is a neceſſary Conſequence of what we have juſt obſerved. The Moon may be in a perfect Oppoſition, and this will happen, if the Centre of the Moon, that of the Earth, and that of the Sun, are in, or nearly in, the ſame Line. The Opacity of the Earth keeps the direct Rays of Light from reaching the Moon; ſhe then is in the Shadow, and totally eclipſed. But if the Centre of the Earth be ſome Degrees diſtant from that Line, which our Imagination may draw from the Sun to the Moon, when in Oppoſition, the Shadow of the Earth ſhall ſlant only over a Part of the lumious Half of the Moon, or may wholly miſs it.

The Time of the Eclipſe of the Sun.

For a like Reaſon, we conceive that the Moon, when in Conjunction, may have its Centre in, or very near, a Line that paſſes through the Centre of the Earth on one Side, and through that of the Sun on the other. In which Caſe it takes from the Earth the Light of the Sun, and either entirely eclipſes, or partly hides it from the Earth. But the Moon, though in Oppoſition, may be diſtant from the ſaid Line one Half of its Diameter or more, and then the

Interpoſition of the lunar Globe cauſes no ſort of Alteration. The very next Day ſhe advances thirteen Degrees more towards the Eaſt than the Sun. She finiſhes her Revolution in twenty-ſeven Days, but meets not the Sun at the ſame Point where ſhe left him after the foregoing Conjunction. As the Sun itſelf advances towards the Eaſt in the Space of one Year, as much as the Moon does in that of one Month, ſhe overtakes and comes under it again not till after nine and twenty Days; but in her perpetual Revolutions her Courſe is varied in ſuch a manner, that ſhe very often paſſes under the Sun without eclipſing it, and is frequently in Oppoſition with it, without being darken'd by the Interpoſition of the terreſtrial Globe.

The faint Light of the whole Body of the Moon during the Creſcent.

You, perhaps, will aſk me, Whence is that faint Light, which overſpreads the whole Body of the Moon during the firſt and laſt Days of its having the Form of a Creſcent? This, as well as the Viciſſitudes, Phaſes, and Eclipſes, is no more than an Effect of the peculiar Motion of the Moon, and of its particular Situation at that Time. The Earth reflects the Light of the Sun upon the Moon, juſt as the Moon herſelf reflects it upon the Earth. When the Moon is in Conjunction, the Earth is in Oppoſition with regard thereto. It then properly is Full-earth with regard to the Moon, and the Beams which the Earth caſts on the the Moon are ſuch, that the Moon may tranſmit it back to us by Reflexion. The whole Moon would then be viſible at the Approach of the Conjunction, did not the Sun, which is then in her Neighbourhood, and which drowns the Light of the Stars, wholly abſord that faint Light from the Earth reflected on the Globe of the Moon. This therefore cannot be ſeen, though there be no Interpoſition of any opake Maſs between it and our Eyes. When the Moon in Conjunction hides a Part of the Sun from us, what remains uncover'd has yet a Brightneſs far ſuperior to the dim Light, which the Full of the Earth may then caſt on the Moon. When this cauſes a total Eclipſe of the Sun, as it then robs great Part of the Earth of all manner of Light, it conſequently ſhall receive none therefrom; much leſs ſhall it ſend back any to us. But when the Moon is a *little* withdrawn from the Sun, and yet the Earth ſtill almoſt in Oppoſition, the Light that paſſes from the enlighten'd Diſk of the Earth to the obſcure Surface of the Moon is there reflected, returns again to us though much weaken'd, and ſhews us the whole Body of the Moon, which not only is border'd with a golden Creſcent, but alſo cover'd in every other Part with a gentle Light, that diſtinguiſhes it from the Azure of the Heavens.

The peculiar Motion of the Moon from Weſt to Eaſt, and the Variety of its Situations, are, as you ſee, ſufficient to give us a very clear Idea of the ordinary Phænomena. Now it would be delightful after that, to be able to foretel the Inſtant when Eclipſes would happen, and the Degree of Obſcuration; to know the Difference of the Courſes of the Moon from one Month to another, and the Rules of its Returns to the ſame Limits after a certain Number of Deviations. But let us not confuſe the Order, which we have propoſed to ourſelves; and reſerving this Geometrical Theory for another Place, let us ſee what is the Deſign of the Courſe and Phaſes of the Moon; it being a Matter of far greater Concern to us, than the moſt learned and moſt exact Calculations.

If I uſe my Reaſon ever ſo little, I find in the Courſe of the Moon a Series of Caution and Cares, which have no other Object but the Conveniency and Welfare of Man. That Body, as maſſy and dark as it is, with regard to the Earth, has been placed in a Point, and an Orb ſo little diſtant from it, that it alone throws a greater Quantity of Light upon us, than all the Stars together, though theſe be as many Suns. Philoſophers ſometimes pity the common People, that know neither the Greatneſs of the Stars, or the Smallneſs of the Moon. But ſuch Philoſophers as ſhall only conſider the abſolute Magnitude of thoſe Bodies, would really be leſs clear-ſighted than the common People themſelves. For theſe perceive in the Moon, not indeed its real Bulk, the Knowledge whereof is of little Concern to us, but a Light far ſuperior in Brightneſs to all the Stars; and from the Relations the Creator has put between that Planet and us, it is evident that he had this good Effect in view. He has removed the Stars ſo very far from us, or keeps us ſo far from them, that the Night we ſtand in need of cannot be impair'd by their Brightneſs; and he has ſituated the Body of the Moon ſo near us, that it becomes a magnificent Glaſs, which returns to us in the Night a great Part of the Light of the Sun, which he had loſt. 'Tis true, the Motion of that Glaſs thus ſucceſsfully placed all round the Earth, has been mark'd out by Lines that heighten or lower in a ſeeming Irregularity. But theſe Wanderings and Deviations are limited, and by their Help the Moon is very ſeldom in an exact Oppoſition, or in an exact Conjunction, that is, very ſeldom deprived of all manner of Light by the Interpoſition of thoſe Planets; whereas, had the Courſe of the Moon been more uniform, we muſt every Year have had as many Eclipſes of the Moon as Oppoſitions, that is, twelve, and likewiſe twelve Eclipſes of the Sun at the Conjunctions. But there are Favours ſtill more ſtriking than theſe.

If a Man has a Mind to ſet out on a Journey before Day-light, or to prolong his Courſe till after Sun-ſet, the firſt Quarter offers its Aſſiſtance, and ſerves him as a Guide immediately after the Sun is retired. The laſt Quarter likewiſe does for his ſake prevent by ſeveral Hours the Dawning of the Day. He may alſo defer his Journey to the time of the Full Moon, which affords him Days, as it were, four and twenty Hours long, by lighting him without Interruption. By this Help he can either avoid the burning Heats of the Summer, or at his Pleaſure ſecurely diſpatch ſuch Buſineſs as muſt not, for his Intereſt, be truſted to Day-light.

But would not a Night always clear have been more advantageous? God, indeed, makes almoſt every where ſeveral Uſefulneſſes agree together; and the Variety of his Favours adds a new Value to their Excellency. The Moon is not only deſign'd to moderate the Melancholy of the Night, by a Light that lengthens out, or replaces that of the Sun. It is a true Satellite, fix'd faſt near Man's Palace, and charged with ſucceſſively filling ſeveral Poſts, and with giving him, in every one of theſe, ſome new Advice, or a new Signal. The Sun was appointed to regulate the Order of rural Works by the Revolution of a Year. But the Moon, by making a like Revolution round us in twenty-nine Days, and regularly changing its Figure at the four Quarters of its Courſe, was deſign'd to rule civil Order, and the common Affairs of Mankind. It offers to all the Nations of the Earth a Watch-light, which takes every ſeven Days a Form entirely new, and preſents them all with convenient Diviſions, with Periods regular, ſhort and fit to determine the Beginning and the End of minute periodical Affairs. Therefore the *Hebrews*, the *Greeks*, the *Romans*, and all the Antients in general, uſed to aſſemble at the time of the New Moon, to diſcharge the Duties of Piety and Gratitude; whatever might be of Concern to them during the new Month, was proclaim'd to them on that Day. They met again at the Full-Moon, and the two Quarters were a couple of other Terms very eaſy to be pointed out, Nay, even to this Day, the *Turks*, the *Arabians*, the *Moors*, ſeveral *Americans*, and many other Nations, refer the whole Order and Oeconomy of their Calendar, to the Renewals and other Phaſes of the Moon. Our being leſs attentive to it than they, does not prevent its being ſtill as ſerviceable to us. The exact and convenient Calculations, which many learned Aſtronomers furniſh us with, free us from all manner of Care and Inſpection that way. But their Calendars and Ephemerides that direct all our Affairs, are themſelves govern'd by Obſervations of the Courſe of the Moon. They are beforehand adapted, proportion'd, and reduced to the Advices, which this watchful Satellite will never fail to give us, till He, who for our ſake order'd it to ſtand Centry, ſhall think fit to change its Functions with the State of Man, in whoſe Service he had originally fix'd it.

THE

THE
CREPUSCLE *and the* AZURE
OF THE
HEAVEN.

DIALOGUE IV.

A Faint Light begins to whiten our Horizon, and we already ſee Day a good while before the Sun, that puſhes the Light towards us, is arrived at the Border of that Half of the Heaven, which ſtands open before us. This Order of Nature has ſomething ſurprizing to us; for we ſee the Light no otherwiſe than by the Rays that reach our Eyes. Now the Sun being as yet in that Part of the Heaven, which is hidden from us, and behind the other Half of the Earth, cannot, it ſeems, ſend any of its Rays directly to us. Doubtleſs, it can make ſeveral of them glance upon the Extremities of the Lands that terminate our Sight. But theſe Rays preceed farther into the Heavens. If in thoſe Spaces, which they go through, they meet with any maſſy Body like that of the Moon, or any other Planet, they ſhall be reflected as in a Glaſs, and a Part of theſe Rays ſhall be ſent back to us; but for want of a Surface, or of a denſe Body capable of reflecting them, they will paſs on, and be all of them loſt, with regard to us. Is there in Nature any particular Body deſign'd to do us that Service? If ſo, ſure the Artifice and Mechaniſm of it will be the greater, becauſe it ſerves us without being perceived, and the Uſefulneſs of it be the more worthy our Gratitude, becauſe this Caution was taken for our ſake alone.

See Paſchal, on the Weight of the Air.

Keill's Aſtron. p. 385, Mr. De Meyran's Auror. Boreal. Sect. 2,

Here you may recal, Sir, what we formerly have remark'd of the Atmoſphere, or that Maſs of rarified Water, and the groſs Air, wherewith God has enveloped the whole Earth. Nor are you ignorant, that the Column of Air, which keeps *Mercury* up to the Height of 27 Inches at the *Foot* of a Mountain, ſuffers it to lower till it is but 25, 24 and 23 Inches, or even leſs, as we draw nearer the Top of that Mountain. Whereby it appears, that the Preſſure leſſens in proportion as the ſaid Column ſhortens; and by judging of the Relation that is between 27 Inches, and three Quarters of a League, (by which Quantity the Height of the Atmoſphere is diminiſh'd at the Top of our higheſt Mountain) it has been found by the plaineſt Calculations, that the Height of the Atmoſphere may be about twenty Leagues. They conjecture, however, after ſeveral Experiments, that this Body may be incomparably higher and more extenſive than it is commonly ſaid to be; and they have beſides unqueſtionable Proofs, that it varies according to the ſeveral Degrees of Heat, Cold, Wind, Agitation, or Repoſe, that are felt ſenſibly in it. It is in the vaſt Reſervoir of rarified Waters, of compreſſible Air, of attenuated Oil, of volatile Salts, and of other Elements wiſely mix'd together, that we formerly found the Origin of the perpetual Courſe of Fountains, the Principle of the Nutrition of Animals and Plants, the Source of Smells and Savours, and many other things of no leſs Importance. All theſe different Bodies, which are toſs'd about in the Atmoſphere, are now no longer the Subject of our Speculations. The mechanical Frame itſelf of the Air muſt be our Study, if we have a Mind to underſtand with any Exactneſs, not only the Birth and Progreſs of Crepuſcles, but even the lofty Order of all Nature.

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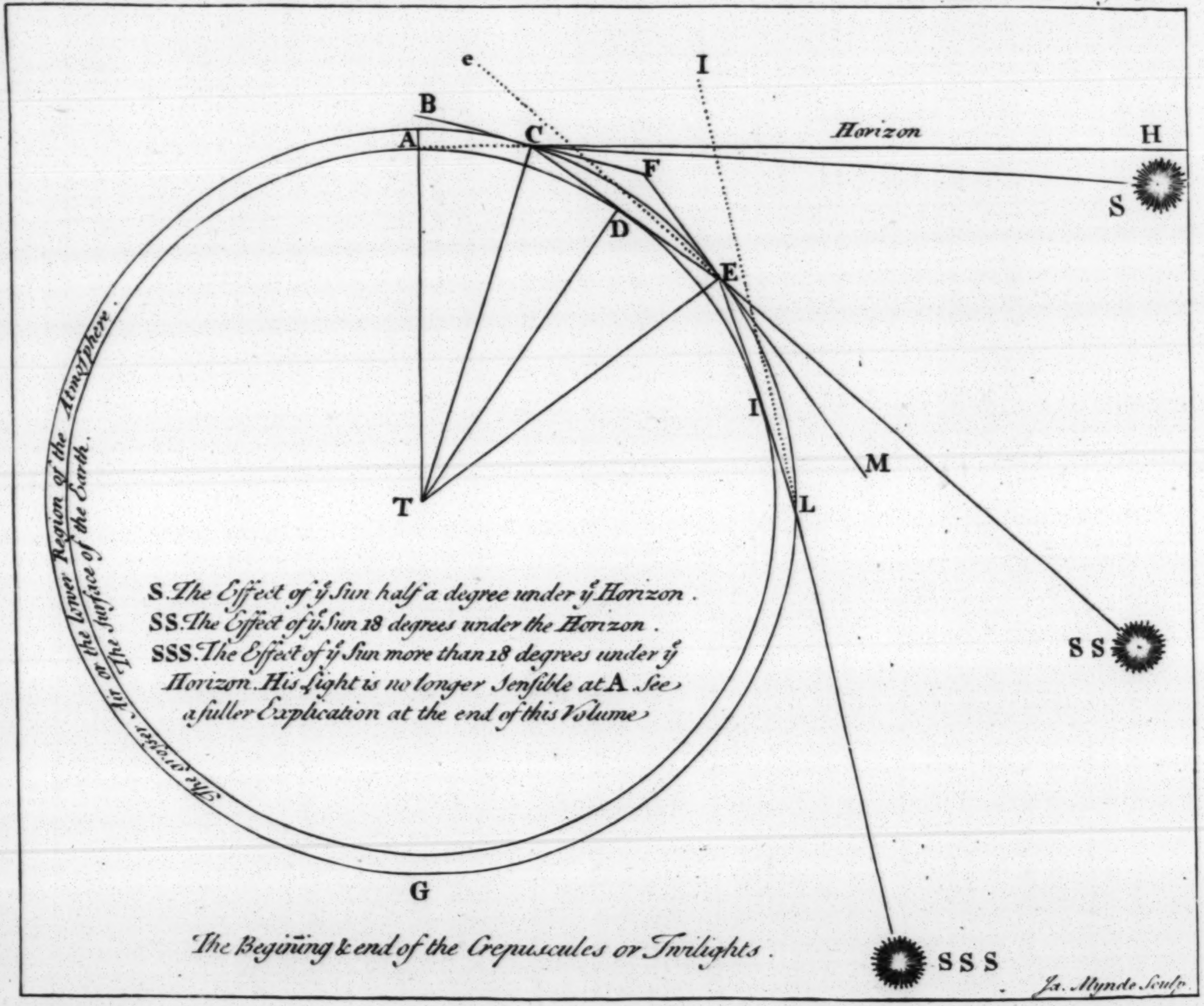
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The grosser Air or the lower Region of the Atmosphere.
The Surface of the Earth.

S. *The Effect of ye Sun half a degree under ye Horizon.*
SS. *The Effect of ye Sun 18 degrees under the Horizon.*
SSS. *The Effect of ye Sun more than 18 degrees under ye Horizon. His Light is no longer Sensible at* A. *See a fuller Explication at the end of this Volume.*

The Begining & end of the Crepuscules or Twilights.

Ja. Mynde Sculp.

The Atmoſphere is framed and diſpoſed over our Heads in ſuch a manner, that, notwithſtanding its extenſive Maſs, it ſuffers us to ſee the Stars, that ſhine at an immenſe Diſtance from it; and, in ſpite of it's Tranſparency, bends and gathers for us an infinite multitude of Rays, of which we ſhould be deprived without it.

Any Ray or Portion of Light, that falls directly and perpendicularly on the Atmoſphere, enters it without any Obſtacle, and through it deſcends on the Earth in one and the ſame Line. But of all the Rays that fall upon it with greater or leſs Obliquity, ſome are admitted into, and ſome are removed from it. When the Sun is as yet more than eighteen Degrees diſtant from the Line, which our Horizon deſcribes in the Heaven, then all the Rays offer themſelves ſo obliquely to the Atmoſphere, that inſtead of entering it they ſlant aſide, and are loſt in the immenſe Extent of the Heavens; like that piece of Slate or Tile, which a Child flings ſloping on a River, and which falling very obliquely on the Surface of the Water, does but skim or graze upon it, bounds and riſes again, and then repeats the ſame thing more faintly, yielding at the ſame time both to the oblique Impreſſion or Impulſe it has received, and to the Weight that forces it downwards.

But when the Sun comes to the eighteenth Degree from the Limits of the Horizon, this is very near the Point where the Atmoſphere begins to admit the Rays that ſtrike it (I ſay, very near, becauſe that Point often varies) the Atmoſphere riſes or ſinks according as it is dilated or depreſs'd. When rarified by Heat, it is higher. Then the Sun, even before it reaches the eighteenth Degree from our Situation, may meet it under that Degree of Obliquity, where tranſparent Bodies have been appointed to admit the Light. On the contrary, when Cold has depreſs'd the Maſs thereof, as it is then flatted and lower, the Sun, when at eighteen Degrees Diſtance from our Horizon, is ſtill below the neceſſary Degree of Obliquity, and it's Rays ſtill glance on the Atmoſphere, inſtead of being admitted therein.

In vain ſhould we here examine into the Reaſon why a Ray is not admitted into a tranſparent Surface, unleſs it makes an Angle of a certain Meaſure with it. It is enough for us to ſee the matter of Fact, together with the Advantages reſulting from that Oeconomy. On this Particular, as well as on any other, we may affirm, that Nature has not, by adjuſting itſelf, added Beauty to the Almighty's Work; but rather, that from God's immediate Intention of procuring that Beauty, Order ſprung with the whole Frame of Nature.

When the Rays offer themſelves under the Degree appointed to enter the Atmoſphere, they not only are admitted into it, but are alſo bent and refracted therein. In the firſt Place, they are bent and lower'd more than they would have been in following the Direction, in which they enter'd the ſame. It is an invariable Law of Nature, that when a Ray of Light obliquely paſſes from one tranſparent Body or Medium into a thicker, as from the Air into the Water, it does not follow the ſame oblique Line in it's Way through it, but bends and becomes ſomewhat more convergent. We ſhall examine the Rules of this Convergency in it's proper Place; we, for the preſent, aim only at knowing the Uſe and Effects thereof.

All the oblique Rays that paſs from the Heaven, and from the lighter into the thicker Part of the Atmoſphere, do not follow their firſt Direction, but are bent therein; which Bending brings them out of their firſt Direction. This begins to brighten our Heaven long before the Arrival of the Sun.

The Reflexion of the Light.

But in order to regulate the Oeconomy of the Crepuſcles, it is not enough that the Atmoſphere bends and drives towards us a vaſt Number of Rays, that would not have reach'd hither, following the Courſe of their firſt Direction. It muſt, beſides, continually reflect the greater Part of theſe Rays; for, really, they are not all puſh'd towards us. The moſt numerous are thoſe that go through, and ſtrike the very Bottom of the groſs Air, which ſurrounds us, whence they are brought again, or reflected on all the Objects about us. This Operation, which by the Bending or Refraction of the Rays cauſes the Dawn of Day, likewiſe produces it's Continuation and principal Beauty, even when the Sun is in its greateſt Degree of Elevation, and caſts on us all its Heat. The Earth, that receives theſe Rays, beats them back on all Sides; they aſcend again into the Atmoſphere, which once more returns us the moſt part of them. Thus does it make them doubly uſeful. Thus it maintains round us that Heat, which is the Soul of Nature, and that Splendor, which is the Beauty thereof.

The Atmoſphere is the Cauſe of Heat.

It evidently increaſes the Heat, ſince it gathers together a numberleſs Quantity of Rays, the greater or leſſer Union whereof is the Meaſure of Heat and Cold. Thus the Atmoſphere becomes to Man a curious Cover, which, without making him ſenſible of any manner of Weight, preſerves all round him that vivifying Heat, always apt to vaniſh, were it not as conſtantly confined.

It is the Cauſe of Splendor.

The Atmoſphere does at the ſame time cauſe and maintain round us that briſk and univerſal Light, which lays our whole Habitation before our Eyes, and which, though it be a neceſſary Conſequence of the Irradiation of the Sun on the Atmoſphere, yet is the Work of the latter, rather than the Production of the Sun itſelf. You certainly will look on this as a Paradox. How! you will ſay; if it is properly the Atmoſphere that produces the Day, by collecting for us the Light, which the Sun caſts thereon; let us for a Moment ſuppoſe the Atmoſphere to be deſtroy'd; in this Caſe we might ſee the Sun without having Day. It then ſhall no longer be the Father of Light?

I admit your Suppoſition. Let the Atmoſphere be no more, and the Earth lie naked under the Sun.

Firſt, The riſing of that Star has not been preceded by any Crepuſcle. It has not been uſher'd in by the Aurora, there being nothing to reflect towards us the leaſt of it's oblique Rays. The intenſeſt Darkneſs covers us to the very Moment of it's Riſing. It ſuddenly breaks out from under the Horizon, ſhews itſelf ſuch as it ſhall appear towards the middle of it's Courſe, and will not in the leaſt change it's Appearance to the Inſtant of it's ſetting, which ſhall be equally tenebrous and obſcure, with regard to us, as the Middle of the darkeſt Night. The Sun, 'tis true, ſtrikes our Eyes with a lively Brightneſs; but under the Suppoſition of the Atmoſphere's being annihilated, it is like a clear Fire, which we ſhould ſee during the Night in the midſt of a ſpacious Field. It is Day light if you will; for we ſee the Sun and the adjacent Objects round us. But the Rays, that fall on ſuch Lands as are a little remote, are for ever loſt in the vaſt Expanſe of the Heavens. Theſe Lands are not perceived, and the Night ſtill continues, notwithſtanding the Fire of this bright and brilliant Star. For inſtead of the white Tint, or Colour, which characterizes the Day, and unveils whole Nature by brightening the Azure of the Heavens, and colouring all the Horizon; we ſee nothing but a black Deep, an Abyſs of Darkneſs, wherein the Rays of the Sun meet with nothing that can reflect them to us. 'Tis true, the Number of the Objects ſhall ſeem to be augmented in the Heaven, and the Stars ſhall be ſeen as well as the Sun. But this is a new Demonſtration, that there is no Day to be had without the Atmoſphere; ſince it is that alone, which, by multiplying the Reflexions, ſtrengthens the Light of the Sun ſo far as to make it drown that of the Stars. The Sun then mounts, if you will, over our Heads; but for want of an Atmoſphere it ſhall always be Night, and the Difference between that Night and ours would conſiſt in this, that the luminous Bodies, which light it now, roll upon a pleaſing and delightful Azure; whereas, in the other Caſe, they would ſeem to be faſten'd on a diſmal mourning Carpet.

You, perhaps, will be at a Loſs to conceive, how the Deſtruction of the Atmoſphere carries with it the Loſs of that fine Azure, that adorns the Heaven, and delights the Earth. But you will eaſily frame a juſt Notion of it to yourſelf, if you do but recall what a prodigious Quantity of rarified Water is raiſed on high, and buoy'd up from the higheſt Part of the Atmoſphere down to us. There never is a greater Quantity of it collected there, than in the fineſt Summer Days, when there are no Clouds, or any Vapours to be ſeen. Thus, though theſe Waters, higher than the Region of the Clouds, eſcape our Senſes, your own Reaſon points out their Exiſtence to you, and the Operations of Nature convince you of the ſame, in Concert with the Legiſlator of the *Hebrews*, who had been inform'd of that Diviſion by the Author of Nature himſelf. It is among theſe Gatherings of Light and rarified Waters always ſuſpended over our Heads, that all the Rays of Light reflected from the Surface of the Land do meet. The Atmoſphere again ſends them back to us from all Parts. This vaſt Maſs of rarified Waters, which ſurround us, being a ſimple and uniform Body in it's whole Extent, the Colour thereof is always ſimple, and conſtantly the ſame. We ſhall afterwards ſee, and in it's proper Place, that theſe Rays of all kinds that are ſent back by the Atmoſphere form the white Colour by their Union. We ſhall ſee likewiſe, that the immenſe Spaces reaching from us to the Stars, not reflecting towards us any manner of Light, muſt needs appear black to our Eyes. The blewiſh colour is what God has given to Water, whether condenſed or rarified. The Atmoſphere, therefore, muſt be of an azure Colour; and this Azure is ſometimes lighter, in Proportion to the Quantity of Rays, which enter the Atmoſphere and are there reflected; ſometimes deeper, when the Abſence of the Crepuſcle heightens the Blue of the Atmoſphere, by means of the Black, which follows it immediately.

How! Thoſe azure arch'd Skies, which we confounded with the ſtarry Heaven, ſhall they be nothing more than a little Air and Water? What we took for the Heaven, ſhall only be a Cover wrapt very cloſe round the Earth! Even ſo. It is indeed nothing elſe; and this again is a new Marvel, that requires ſomething more than a bare Admiration. It is the completeſt Demonſtration of our being the Objects of the tendereſt Affection of the Creator. 'Tis true, a few ſmall Bubbles of Air and Water are of themſelves Things very inſignificant. But that Hand, which had with ſo much Art and Caution placed them over our Heads, has done it merely that his Sun and Stars might not be render'd uſeleſs to us. He imbelliſhes and enriches whatever he pleaſes, and theſe Drops of Water and Air become in his Hands an inexhauſtible Source of Bleſſings and Glory. He fetches out of them thoſe Twilights, which ſo uſefully prepare our Eyes for the receiving of a ſtronger Light. He fetches out of them the Brightneſs of the Aurora; from them he draws the Splendor of the Day, which the Sun of itſelf could never procure us. He makes them contribute to the Increaſe and Preſervation of the Heat, which nouriſhes all that breathes. Of them he makes a bright Arch, that enchants the Sight of Man on all Sides, and becomes the Cieling of his Habitation. God might have made that Arch darker, or even black. But the Black is a ſad and diſmal Colour, that would have thrown whole Nature, perhaps, into the deepeſt Melancholy. The Red and White were as little proper for it, ſince their exceſſive Brightneſs would have offended every Eye. The Yellow is reſerved for the Aurora. Beſides, a whole Arch of that Colour would not have been ſufficiently diſtinguiſh'd from the Stars that were to be ſeen through it. The Green, as it is very ſympathetic and pleaſing to our Eyes, would, indeed, have produced all the neceſſary Embelliſhments. But it is with that lovely Colour that God has adorn'd our Abode. It is the Carpet he has ſpread under our Feet. The Blue, without any Sadneſs or Hardneſs in it, has the additional Merit of cutting open, and ſetting off, the Colour of all the Stars.

The Workmanſhip of that Arch is ſuch, that though it limits our Sight by it's Thickneſs, yet it is tranſparent enough to let us extend our Sight as far as the Stars. Though it is ſo very near us, yet it ſeems to make but one Body with the Stars, that are at an inconceivable Diſtance from it. It becomes to us the Bond of the moſt disjoin'd Pieces. I then ſhall ask all ſincere Hearts, Why has God ſpread this Atmoſphere round us? A falſe Philoſopher will take it for the Sediment of ſome Vortex, and think he has hit it very right. Piety, more penetrating, ſees therein what ſtrikes the Eyes of all; I mean, an evident and palpable Intention to eſtabliſh Man in the Poſſeſſion of Nature, and to preſent him with an Oeconomy and a World deſign'd for him alone, ſince he is the only Spectator of it.

I cannot take my Eyes from this luminous Arch, which affects me leſs by it's Magnificence, than by the Bleſſings it procures me, and by that innumerable Series of Precautions that have been taken for my ſake. But while I follow the Order of the Thoughts, which the firſt Dawnings of the Day might raiſe, I perceive the Beginning of the Aurora. Let us not give ourſelves over to the

Pleaſure of examining this new Decoration, before we have taken Notice of the chief Benefit of the Twilight. The Deſign of this was, no doubt, to prolong the Day; that Man might alſo prolong his Work and Travels, and at the ſame Time not to bring Day-light upon him, before his Eyes were prepared for it; nor the Dark, before he was forewarn'd of it.

But the Crepuſcles vary from one End of the Year to the other, and they are far greater towards the Poles, than in the Torrid Zone. Is there then the ſame Artifice and Utility in the Variations of the Crepuſcle, as in the Cauſe that produces it?

The Inhabitants of the Torrid Zone ſee the Sun aſcending perpendicularly their Horizon, and going down in the ſame Direction into the Under-hemiſphere. Whence it happens, that the Sun comes very ſoon to be eighteen Degrees below the Horizon, and leaves them in the darkeſt Night. On the contrary, as it caſts its Rays obliquely towards the Poles, and goes not very far below the Horizon of thoſe, who are near them; it thence happens, that their Nights, though very long, are always accompanied with Crepuſcles, and are in a Manner luminous. The deep Gloom of the Night again brings with it a comfortable Coolneſs to the Inhabitants of the Torrid Zone, whoſe Spirits the exceſſive Heat of the Day has entirely exhauſted. The Remains of an almoſt continual Light are extremely precious to the People neighbouring on the Poles, and free them from a Darkneſs, that would render their Life unhappy. It is a Bleſſing to the former, to have almoſt no Crepuſcle at all, and it is no leſs agreeable to the latter, that they have an Aurora, which is ſcarce ever interrupted.

As for us, who are placed nearly equally diſtant from the Inhabitants of the torrid, and thoſe of the cold Zones, we, by Experience, have ſuch Crepuſcles, as diminiſh in Proportion to the ſhortening of the Days, and increaſe nearly in Proportion to their lengthening. At firſt Sight, this Oeconomy ſeems grievous to us, and one might be apt to think, that as we can do without Light very well, when Nights are very ſhort; we, on the contrary, ſhould be very glad of a fine Crepuſcle, when they are very long. But nothing would be worſe managed than the

Government of the World, were it wholly left to the Conduct and the Reaſon of Man ; and nothing can be better contrived than what God has eſtabliſh'd, even when it ſeems contrary to our Notions. Of this you may judge by the Oeconomy of the Crepuſcles, of which we might be inclined to complain.

Nights become longer, and the Darkneſs deeper, after Man has gather'd in all his Harveſts. Then the Earth, no leſs than he that tills it, wants to take its Reſt ; Winter comes to refreſh them both, and to make them recover, during the Time of Inaction, the Strength neceſſary, ere long, to begin Labour a new. Night may lengthen without any dangerous Conſequence, when the Husbandman is unemploy'd, as is Nature itſelf. What would Crepuſcles be good for, while Man is at Reſt ?

But Night will gradually gather up its Veil, and yield Man new Degrees of Light, as the Neceſſity of working ſhall bring on the Neceſſity of being lighted. During the Summer Night, for the Sake of Man's Works, continues to lengthen out the Crepuſcle for his Uſe, even when it has begun to lengthen itſelf out by a ſenſible Diminution of the Days. When the great Heat ſhall ſollicit Man to cut down the Graſs, or the Corn, it has brought to perfect Maturity, Night then, leſt he ſhould be deſtroy'd by the Heat of a burning Sun, invites him to put off a great Part of his Toil to the Time when ſhe comes to cool him. To gratify him, ſhe becomes an almoſt perpetual Aurora. In the Summer-ſeaſon, a faint Light, more or leſs conſiderable, conſtantly chears the Horizon towards the Evening between the Weſt and the North, and between the North and the Eaſt towards Morning. Man ſees diſtinctly what comes under his Sickle or Scythe, and the Mildneſs of the Air allows him to cut his Harveſt down without ſweating. The Summer, which renders his Travels more eaſy and convenient to him, and facilitates the Fiſhing and Trade of the North, accommodates itſelf to all his Wants, and kindly lights all his nocturnal Operations, at the very Time when the Reſt he takes, during the Heats of the Day, renders his Night-watches neceſſary.

Here, my dear Chevalier, I would fain aſk you, among all the Methods one may follow in ſtudying the Oeconomy of Crepuſcles, pray, which would you give the Preference to? I, for certain, blame none of them; but I may be allow'd to try your Judgment. The Order of Crepuſcles may be ſtudied after the Method of the Philoſopher, or after that of the Ploughman. The former calculates the Difference of the crepuſcular Light from Day to Day, and his Work may be ſo exact as to procure him general Applauſe. The Husbandman is not ſo learned; but at thoſe Hours, when he is at leiſure from his Work, he ſometimes reflects upon the Heat that ripens his Harveſt, during the Day, and on that gentle Light, which comes to aſſiſt him to cut it down during the Night. He is concern'd at ſeeing the Coolneſs concurring with the Light, to forward his Labour. He perceives God's Intention in this beautiful Oeconomy, and renders him therefore Thanks and Praiſe. Both theſe argue and philoſophiſe after their own Manner. But if the firſt has look'd upon the Atmoſphere, wherein the Crepuſcle is produced, only as a duſty Maſs of Matter, which Gravity has collected round the Planet; if he has neither diſcern'd or adored the Hand that rules and inſures Light to Man, by lodging him in the Concavity of an Atmoſphere; pray, which of our two Philoſophers do you prefer? Which, do you think, argues beſt? You, no doubt, have a Value for Calculations and Exactneſs; but I am ſure you will declare for the Philoſophy of the Mind.

THE
AURORA.

DIALOGUE V.

HEAVEN and Earth change. Every Moment brings with it ſomething new. That Circle, which clear'd up and whiten'd the Azure of the Firmament towards the Eaſt, now widens and riſes upwards. The Objects, which we had much ado to perceive, being now to be clearly diſtinguiſh'd. It is Day-light in ſhort, and the Crepuſcle is at laſt ſucceeded by the Aurora.

* Poets, who know no better Method of pleaſing than that of making lively Pictures of Things, have given us the pleaſanteſt Deſcriptions of the Aurora. They make her the Daughter of the Air, and ſtile her the Forerunner of the Day. In this Quality ſhe is charged with the Cuſtody of the Gates of the Eaſt, and it is ſhe, who, at the appointed Time, comes to open them with her roſy Fingers. She ſends before her the Zephyrs, to ſcatter gloomy Vapours, and to purify the thicken'd Air. Wherever ſhe appears, ſhe enlivens the Verdure, makes Flowers grow under her Steps, and with News of the coming Day, ſpreads Beauty and Joy all over the Univerſe.

Theſe

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* Ἠριγενεία φανὴ ῥοδοδάκτυλος ἤως. Homer. Odyſſ.

Theſe poetical Fancies have ſomething in them very agreeable, but the fabulous Strokes, with which Truth is blended therein, are nothing but a Paint that disfigures it and impairs its Beauty. Let us then leave the poetical, and conſider the natural Aurora. This, indeed, is ſo majeſtical and ſo bright, that it wants no borrowed Help, or Decorations, to be infinitely pleaſing.

Aurora with regard to us, is a Creation entirely new, and every whit as generouſly gratuitous as the firſt Creation was. It is wholly new, ſince the Aurora makes Heaven and Earth riſe out of that profound Darkneſs, which took from us the Sight and Uſe of them, as if they were no more. It may even be ſaid without derogating from the exact Truth, that the Birth of Light is finer and more magnificent at preſent, that it was at the firſt Moment of its Creation. There were then no Spectators, nor any Objects to be enlightened. The Earth, 'tis true, was already made. God had formed the ſeveral Paras of Matter, he had with Oeconomy ſpread the various Strata or Layers, and prepared all the Organs thereof. But the Animals, the Plants, and all the Works wherewith it was to be covered and adorned, were not as yet upon it. They appeared thereon but ſucceſſively, and within the Compaſs of ſeveral Days, as God was pleaſed to regulate their Being, and aſſign them their reſpective Places. The Waters of the Atmoſphere had not yet been raiſed on high, and thoſe of the Sea not yet collected and confined within the lower Places wherein they now ſojourn. Theſe Waters covered the whole Earth. In ſhort, it was as yet without either Order or Beauty. But now, when the Dawning of the Day ſcatters the Darkneſs, it opens to our Sight an Earth ſtrewed with Bleſſings, and embelliſhed for our Sakes, with the moſt coſtly Attire. It unveils every Thing to our Eyes. It ſhews the Mountains, with the ſpacious Woods wherewith they are crowned. It offers to our View the leſſer Hills, with the Vines, that are like Tapeſtry upon them; the Fields, with the Crops that cover them; the Meadows with the Rivers that water them. It draws the Curtain from over whole Cities and Towns. It brings out of Darkneſs the Domes and Pyramids of Temples, the magnificent Caſtles of the Great, and the Abodes of the People diſperſed all over the Plain.

All theſe Treaſures were loſt to us, ſo long as the Night made them of no Uſe. It ſeem'd to rob us of them, or to annihilate them; and as we have no Title to the Day that reſtores them to us, the Return of the Aurora is of courſe a Favour, not only as new and as magnificent, but likewiſe as little deſerved, and as greatly bountiful, as was the Favour of Creation,

God, it is true, creates no new Beings in the material World; and in that Senſe he is, indeed, enter'd into his Reſt. But as nothing began to exiſt but becauſe he was pleaſed it ſhould be; and as every Thing would ceaſe to be and to act, ſhould he ceaſe to will their Duration, Motion, and periodical Return *; he acts as much at every Inſtant for the Preſervation of the Univerſe, as he did at the firſt Moment of it's Creation. He then began to will that it ſhould, and he continues to will that it may, ſubſiſt. Therefore each new Day is as frank, and as gratuitous a Gift from Him, as was the firſt of all Days.

But People will, perhaps, argue thus. Why have you here Recourſe to the Will of God, when your only Buſineſs is to follow the Order of Nature? It is a wrong way of reaſoning, to look for Intentions, and to ſuppoſe any particular Gifts in the Return of the Aurora. It is nothing more than the Beginning of a new Revolution of our Vortex, and a mere and plain Conſequence of the Laws of Motion; it is, indeed, an immediate Effect of the Motion, or of the Revolution of the World. But there may be ſome Danger in the Manner, in which Naturaliſts ſpeak of Motion to ſuch as liſten to them. They give young Folks an Opportunity of miſtaking, and of making Motion or Nature an Idol, which they place in the Room of God, and to which they attribute every Thing, as to it's neceſſary Cauſe. Whence it happens, that while they think themſelves to know Nature better than the reſt of Men, they really know neither God nor his Works, and become Idolaters inſtead of ſpeaking Senſe. And really, what are Motion and the Laws

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* My Father worketh hitherto, John. v. 17.

Laws of Impulſe? Motion is evidently nothing but the Body moved or diſplaced. The Strength of Motion, and the Duration of Motion are nothing but the conſtant Order and Oeconomy, which God has preſcribed to himſelf, and according to which, he regularly continues to preſerve and diſpoſe of every Thing. The Laws of the claſhing of Bodies one with another, or thoſe of Percuſſion, are the ſame with the Decrees, by which God has regulated theſe Claſhings. The Velocities of Tranſportation are nothing but the Execution of his Sovereign Order. In ſhort, the moving Force, the Nature of which Philoſophers are ſo much at a Loſs how to determine, is in reality nothing but the Action of God, differently applied or diſtributed with Oeconomy and Deſign. A Body moved continues it's Motion in a ſtraight Line, till it meets another Body. Not that, after having traverſed the Space of one Foot, it has acquired any real Force, to go through a ſecond; but becauſe that Continuity of Tranſportation, and the Alterations that happen in the Claſhing or Percuſſion, are Conſequences of the Scheme whereby Nature is ruled; and this Order ſubſiſts, becauſe God is faithful in the Execution of his Plan. But as he follows it with an entire Liberty, there is no manner of Neceſſity, that Night ſhould be ſucceeded by the Aurora, or this be ſucceeded by the Sun, whoſe Arrival it foretels. I ſhould then argue with as much Stupidity as Ingratitude, ſhould I go no farther than obſerving in the Aurora the four and twentieth Part of a daily Revolution, inſtead of adoring in it that free, efficacious, and perſevering gracious Will, that frees us again from Night and Darkneſs, in reviving the Light for our ſake, and which, with the Day, renews the Service of all Creatures, for us.

To this Favour of the renewing of the World, the Aurora adds another not far inferior. It makes Man himſelf revive, in raiſing him from Sleep, which to him is a ſort of Death. The Morning, reſtores him to the, Uſe of his Underſtanding, his Arms, and his Talents, whereof Sleep had entirely robbed him. It warns him of the Time when he is to return to his Work. This Office would not make Aurora agreeable, were working a mere Trouble. But as it is the neceſſary Exerciſe of Virtue, it is likewiſe the Source of true Happineſs. The Aurora comes on, without any Variation, or giving any Quarter, to declare the Hour of Labour. It lays Man under Conſtraint for his own Service. It comes to ſtrike vigorouſly on his Eyes. It has already taken the Care to make all his Servants get up. He whoſe Charge it is to wake the reſt, has faithfully told them before hand, their Maſter was ready to ſet out; and leſt Man ſhould find them aſleep at the Hour of his waking, the Cock has ſeveral times repeated his Summons; all in ſhort moves according to Order. The reſt of the Birds are in the Fields before Man. They fill the Air with a thouſand and a thouſand pleaſing Notes that reach his Ears, and gently finiſh his waking. The Beaſts of Burden and Cattle wait only for his Orders, and make themſelves ready to move on the firſt Signal. Man at laſt leaves his Bed and Houſe, and all attend him. For, in all the Villages within my Sight, I ſee Husbandmen follow'd by their Horſes; Travellers on Foot, in Coaches, or on Horſeback; Shepherds at the head of their Flocks, and Workmen loaded with their Tools. The Roads, Bridges, Ports, Markets, and all publick Places, begin to ſwarm with People. All Mankind are in Action. The Aurora has denounced the Hour of working. It is ſhe that cauſes this univerſal Motion.

The retiring of wild Beaſts.

But when I ſee Man ſet out for his Work, with all the Animals that ſerve him, I am amazed to ſee ſome that chuſe that very Moment to retire to their Abodes, and which go to Reſt, or hide themſelves, inſtead of enjoying the Charms of broad Day-light. I don't mean thoſe melancholly Birds, who are ſcared by the Light, but I mean a great Number of Animals, which are no Enemies to it. If I take my Eyes from the Plains, to obſerve what paſſes at the Entrance of the Woods, I ſee here Rabbets retiring; then Wolves or Foxes; in another Place Harts and Hinds, follow'd by their Fawns; in ſome other Place wild Boars, attended by a Herd of their Young. Sometimes a Deer or a Roe-Buck; ſometimes other Animals, that are either cruel or capricious, but all of them wild and untractable. What can thus force them to retire? Is it the Light? No, ſure.

That pleaſes them ſufficiently. They enjoy it as long as they can; they haſten not to be deprived of it. It is evident from their ſlow and often interrupted March, that they re-enter Darkneſs much againſt their Inclination. What then can thus drive them from the Plain, where they all find their Subſiſtance? Is it the Sight of Men? But theſe are very remote; and thoſe, who ſhew themſelves, are without Arms, or any other Caution or Defence. One ſings in getting ready his Plough. The other tries his Pipe, lying on the Graſs by his Dog, whom perhaps he has tied up. The Traveller purſues his Journey with the utmoſt Indifference. There is no manner of ill Deſign, nor any Declaration of War. Nevertheleſs, all theſe Animals get into the Woods, as well in thoſe Countries where there are no Hunters, as in thoſe, in which they are moſt formidable and troubleſome to them. Therefore, it is not Terror, which calls them together into the Woods. Were they frighten'd, they would run precipitately; Their Retreat would be a real Flight. How can Man not perceive, in this Diſpenſation, the Work of that Providence, which ſubmits every thing to him? She has treated him as the abſolute Maſter and Proprietor of the Place he inhabits. When he is pleaſed to go out to viſit his Dominions, the wild Beaſts that are to ſerve him, without ſhewing themſelves, or being any way troubleſome or expenſive to him, leave him the Place free; and though it be more eaſy for them to find their Food in the Plain by Day than during the Night, the Aurora, by introducing Man there, warns all wild Beaſts not to appear. They know the Hour and Signal, and reſpectfully get out of the way. An irreſiſtible and powerful Hand, in ſpite of them, drives them into the Foreſts, and the Lord of the Earth ſees nothing that can any way interrupt his Work, or reſtrain his Liberty.

The domeſtic Animals, and thoſe that live by him, behave with reciprocal Diſcretion with regard to the wild. They never go, without Commands, to annoy them in their Solitude. They even keep from them with a kind of Prudence, and are ſenſible of the Danger approaching them too near. They all know their Bounds, and keep within the Limits of their appointed reſpective Diſtricts. From this their noble Oeconomy, in which Man has not the leaſt hand, reſult a thouſand and a thouſand Advantages concerning us alone.

The Wind and the Morning-Dew.

As the Aurora riſes, we receive ſeveral other favours of quite different kind. The Sun had, during the whole foregoing Day, raiſed from the Surface of the Plains and Waters a vaſt Quantity of Bubbles of rarified Water and Air, and drawn them very far from the Earth. Thoſe that were laſt raiſed, had immediately fallen again at the going down of the Sun, and the withdrawing of it's Heat. They had gather'd again in their falling, and form'd the firſt Coolneſs of the Night, which is called Dew. But all the other Bubbles, which in the long continued Day had got through the groſſer Air, and placed themſelves in Equilibrio with the upper Parts of it, in the ſuperior Regions, had remain'd ſuſpended therein during the calm of the Night. At the Approach of the Sun, the firſt Efforts of its Heat, beginning to affect the Air grown cool and condenſed, neceſſarily dilate it. One quantity of Air dilated by the Heat puſhes another, which is reſiſted by a third. This Emotion of the Air becomes a Wind, ſometimes gentle, ſometimes cool, and as piercing as the North-eaſt Wind. The Atmoſphere is more or leſs agitated by it. The rarified Water is toſs'd by theſe ſhocks, that make it condenſe or gather again. Such is the Zephyr, which the Aurora employs to carry before her the Dew, which becomes the moſt delicate Nouriſhment of Plants. The Earth drinks it in; the Leaves of Trees, like ſo many open Hands, bow in order to receive it, and the Flowers open on all ſides to partake of that Treaſure. The coming of the Aurora is to theſe Productions a moſt precious Moment, which by inſinuating ſo light and ſo fine a Diſtillation into their Pores, conveys therein at the ſame time a thouſand and a thouſand Particles of Oil, Salt, and Air, which the Action of the Sun ſhall afterwards diſtribute through the whole body of the Plant.

The Beauty of the Heaven at the Approach of the Sun.

But let us not be ſo entirely taken up with the Good and Favours done to us, as to forget to beſtow a part of our Attention on the Delight that heightens them. I ſee the whole Circle of the Horizon gradually inflamed with the brighteſt red. The Clouds every where contract various and lively Colours. The Edges of the thickeſt among them become Fringes brighter than Silver. The thin Vapours that croſs the Eaſt, there become like Gold. The Green of the Plants, attenuated by the Drops of Dew, which cover them, give them the Sweetneſs, and all the Luſtre of Pearl. But though Nature be extreamly beautiful at that Moment; yet are we ſtill more attentive on what it makes us expect, than affected by what it lays before our Eyes. The perpetual Increaſe of the Aurora, makes us ſenſible, that it forebodes ſomething ſtill more perfect. It is a gentle Medium, which by gradually gathering Strength, facilitates the Paſſage from Darkneſs to broad Day-light. Each Moment adds ſomething to the foregoing. We go from Light to Light. We long to ſee the Fulneſs of it. What of it is granted to us for the preſent, yields no more than a Foretaſte, and makes us long for what is the Source and Spring thereof The Hour is determined, when it ſhall appear in all its Glory. The happy Moment is near at hand, but ſtill expected.

THE
RISING
OF THE
SUN.

DIALOGUE VI.

NATURE, at laſt, preſents us with its moſt glorious Object. The Sun riſes. One ſingle Ray eſcaped from behind the Top of the Mountains, which before intercepted the Sight of it from us, firſt darts from one End of the Horizon to the other. New Tracts of Light follow, and give new Strength to the firſt. The Disk of the Sun diſengages itſelf by degrees. It now is ſeen entirely, and aſcends the Heavens with a majeſtick State, which attracts and fixes all Eyes upon it.

It's Unity.

A few Moments before I perceived an innumerable Multitude of Flambeaux on every ſide. But the Light they all together yielded me, did not render the Earth viſible to my Eyes. They were indeed of ſome Uſe, to make me diſtinguiſh what was round me, at very ſmall Diſtances. But even among all theſe Fires I remain'd ſtill in the Dark,

Dark. Now in the whole Immenſity of the Heavens a ſingle Flambeau ſtrikes my Eyes, and it not only makes me amends for the Loſs of the other Lights, drowning them all by the Superiority of it's own, but even overſpreads Nature with ſuch a Splendor and Glory, as changes the whole Face thereof.

What then can be that Globe, which alone cauſes a general Renewal at the very Inſtant of it's Appearance? In vain do I caſt my Eyes, and fix my Attention upon it; I can by no means bear it's Aſpect, and it's inmoſt Nature eſcapes all my Reſearches. Is it a Globe wholly compoſed of Fire? What are the Fire and Light, which it caſts from all Parts? Are the Light and the Fire but one and the ſame material Being? Or are they two diſtinct Things, which go together, and one whereof continually puſhes forward the other? How can that Globe operate ſo powerfully, and at ſo vaſt Diſtances? How comes it, during the ſix thouſand ſucceſſive Years it has lighted and heated Nature, not to have loſt the greateſt Part of it's Subſtance, by the conſtant Effluvia of it emitted therefrom? Has it then a Reſervoir that repairs all it's Loſſes? Is there a perpetual Circulation of Fire and Light, that inceſſantly replaces in the Sun what is uninterruptedly emitted therefrom? Or is the Action of the Sun no more than a powerful Preſſure of its Fires on the Body of the Light, ſo that that Star communicates its Action to us, without undergoing the leaſt Diminution or Loſs? We ſhall, perhaps, hereafter explore the moſt plauſible Anſwers that can be made to theſe ſublime Queries. Let us for the preſent confine ourſelves within what is paſs'd all Diſpute, and inform ourſelves of what may be replied upon with Certainty, on the Meaſure, Diſtance, and Operations, of that Globe. God at preſent hides from us nothing but what is uſeleſs or dangerous; and it would be acting contrary to our Intereſt, (to which God has proportion'd the Knowledge he gives us of his Works) ſhould we reject the Truths he reveals to us.

It's Diſtance and Size.

Geometricians have a Way equally plain and ſure to meaſure inacceſſible Bodies. When they know the Meaſure of one Side and two Angles of a Triangle, they quickly determine the Quantity of the third

Angle, and the Length of the two other Sides. Or, when two Sides and one Angle are known, they immediately find out the other two Angles, and the unknown Side. By this Skill, about which I ſhall in another Place have an Opportunity of entertaining you, it is, that they daily inform us what the exact Height of a Tower or Hill can be, without aſcending it; what the Depth of a Well, without going down to the Bottom of it; and the Breadth of a River, without coming near the other Shore. In like manner Aſtronomers know how to deſcribe a Triangle, of which they know one Side exactly, which repreſents the Semi diameter of the Earth. They beſides know the exact Meaſure of the two Angles form'd upon that Side, by two Lines that meet together in the Centre of the Sun. Thus they know the exact Meaſure of the two Sides that repreſent the Diſtance of the Earth from the Sun. By theſe, or ſome other no leſs certain Operations, being Matters of Fact, on which you may ſurely depend, they judge of and determine the Magnitude of Stars. 'Tis true, the Obſervations of the Moderns have greatly ſwell'd the Calculations of thoſe that were before them. Which is a Proof, not that this Science is frivolous, but that the Inſtruments, therein made uſe of every Day, acquire a new Degree of Perfection. However, as a ſingle Minute, or even a Part of it added or retrench'd, immediately makes a Difference of ſeveral Hundreds of Thouſands, or even Millions of Leagues; let us here ſtick to the groſſeſt Calculations, and to Sums that may have no other Fault but their being inferior to the Reality of Things. Thus we ſhall run no other Risk, but that of ſetting on the Works of God a Price inferior to their true Value, and avoid the Danger of admiring therein a Beauty that ſhould not be in them, or ſome Marvel, the Exiſtence whereof might be doubtful.

There is no Aſtronomer now-a-days, but knows by evident Proofs, and by the plaineſt Calculation, that the Sun is almoſt a million of Times bigger than the Earth. Let us here be contented with aſſerting, that the Maſs of the Sun is a hundred thouſand Times bigger than that of our Sphere. Beſides which, there is no Aſtronomer that does not judge the Sun to be diſtant from us above five thouſand Times the Breadth or Diameter of the Earth. And as that Diameter * is above three thouſand of our common Leagues long, taking only two thouſand Fathom for each League, if we multiply 5000 by 3000, we are ſure that the Sun is above fifteen millions of Leagues diſtant from the Earth. We ſhould be frighten'd at the Thought of what the moſt learned and moſt exact Aſtronomers, in their Workings, add to theſe Meaſures. Meſſ. *Caſſini* and *Newton* judge the Diſtance of the Earth from the Sun to be ten thouſand Diameters of the Earth, which makes thirty, or even thirty-three millions of Leagues. If I confine myſelf to the Half of the Product of their Calculations, notwithſtanding the Exactneſs and Regularity, which no body will refuſe to aſcribe to theſe great Men, of courſe I ſhall not be ſuſpected of any Intention here to augment the Marvellous.

To be made the more ſenſible what a prodigious Space that Half ſtill is, imagine to yourſelf a Horſe, and a Cannon-ball, that ſtart from the Earth in order to get to the Sun, and continue their Way with a ſteady Pace without any Faintneſs or Interruption. Let us ſuppoſe the Horſe to make his Journey of 25 Leagues a Day; and the Ball to go through the Space of an hundred Fathom every Second. In multiplying 25 Leagues by 365 Days, the Horſe would make 9125 Leagues in a Year. After having travell'd at this rate for 1550 Years, he ſhould yet have made no more than 14143750 Leagues. The Ball that goes through a Space of one hundred Fathom in a Second, would make 60 times as much in one Minute, that is, 180 Leagues every Hours. This would make 4320 Leagues a Day, and 1576800 Leagues a Year. Thus the Ball, after having continued it's Motion for nine Years running, yet would have gone through but 14191200 Leagues. If nine Years are not

ſufficient

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* The Diameter of the Earth is 2864 common Leagues long, the Semidiameter being, according to the Calculations of the Gentlemen of the Academy of Sciences, 1432 Leagues, of 2282 Fathom each League, which makes a Produce of 6535648 Fathom. That is, at leaſt one million and a half of Fathoms more than in the Calculation we have choſen to go by for the Conveniency of the Reader; which Calculation is the more certain here, on account of the Meaſures being taken too little.

ſufficient to the Cannon-ball; if fifteen Ages and more, are not enough to the Horſe to arrive at the Sun, according to our Calculation, which falls ſo very ſhort, nay, which is not even half of what is demonſtrably known, and Matter of Fact; at what Period of Time would they arrive, were they to complete the juſt Meaſure, which eſcapes our Sight, and which may conſiderably be lengthen'd for one ſingle third or fourth of a Minute, which neither our Eyes, or any of our Inſtruments are able to take in?

This Diſtance, which ſurprizes us, is however very inconſiderable, in compariſon of that we afterwards ſhall find between the Earth and the Planet *Saturn*; between the Moon and the fix'd Stars; between one Star and another.

The Advantages of that Situation.

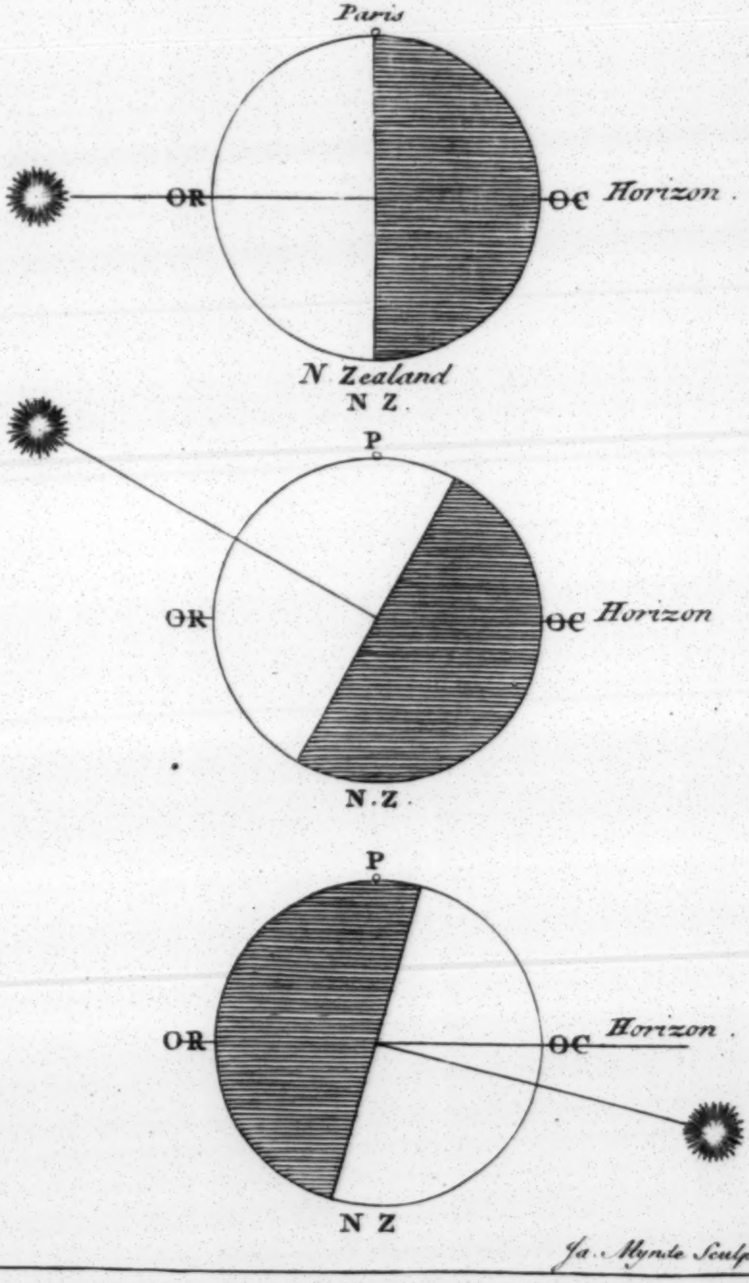
But that he, who diſpenſes Exiſtence at his Will, and is abſolute Maſter of Matter, ſhould multiply, extend, enlarge it, and put a ſort of Immenſity to his Works, is not properly what ſurprizes me; or at leaſt my Amazement hereon is chiefly founded on my own extreme Littleneſs. But what aſtoniſhes and affects me with much greater Reaſon, is to ſee, that, notwithſtanding my extreme *Petiteſſe*, a Hand no leſs beneficial than maſterly has vouchſafed to regulate that Diſtance by the Advantages I was deſign'd to receive therefrom; and has placed the Sun, with regard to the Earth whereon I was lodged, at ſuch a Diſtance, that it might be near enough to warm me, and ſufficiently diſtant from it not to raiſe a Conflagration thereon.

The fiery Rays that proceed from a Globe of Fire, a hundred thouſand, nay, a million times bigger than the Earth, muſt needs have an inconceivable Activity and Force, ſo long as they remain cloſe to one another, and act, as it were, in Concert. They afterwards muſt neceſſarily be divergent, that is, more and more diſtant from each other, as they advance from their common Centre towards the vaſt Circumference, which is enlighten'd by the Sun; and their Force diminiſhes in proportion to their Diſtance at the Extremities thereof. This Divergency of the Rays of Light may be eaſily conceived from the Emblem of the Spokes of a Wheel, which

are

Plate 3. Vol. IV. Page 53

The Effects of the Sun upon the Horizon without an Atmosphere, the Eye looking towards the South.



Ja. Mynde Sculp.

are very cloſe at the Nave whence they ſpring; whereas towards the Fellows or Jaunts, where they end, they become more diſtant, as the Circle of the ſaid Jaunts enlarges.

Our Earth, had it been placed in a Point, in which theſe Rays would have deen ſtill too numerous, and too near each other, could never have borne their burning Heat. Had it been placed farther off towards the Extremities of the ſolar World, it would have received therefrom but a faint dim Light, inſufficient for its uſual Productions. It ſtands in that very Place, where it is ſecured from all thoſe Inconveniences, which it had to fear, and within the Reach of all the Advantages and Bleſſings it could deſire.

In vain one would pretend not to admire this fine Order, and look upon the exact Situation of the Earth, as a neceſſary Effect of Gravity, and of the mutual Attraction of Bodies. Thoſe, who talk of Attraction and Gravitation, may poſſibly underſtand themſelves. But did the Gravity, which, if you will, regulated the Place of the Earth, form likewiſe the Atmoſphere, which ſurrounds it? You already know the Artifice, Mechaniſm, and Structure thereof. Another Obſervation will finiſh your Conviction, whether it is the Fall of a wandering Duſt attracted or preſs'd, that has form'd the Earth in the Place it actually fills, and thrown a tranſparent Atmoſphere between her and the Sun; or a ſpecial and perfectly free Will, that has for the Good of Man regulated the Structure of the Earth, its Diſtance from the Sun, and the Correſpondence of our Atmoſphere with that Star.

Imagine with yourſelf the Earth to be expoſed to the Rays of the Sun, as a Ball to the Light of a Flambeau. There can be but one Half thereof enlighten'd. Let us call the uppermoſt Point of the Ball *Paris*, or *P*; and the undermoſt *New Zealand*, or *N Z*; becauſe that Southern Land is not very remote from the Point of our *Antipodes*. The two lateral Points, which are at equal Diſtance from the foregoing, we ſhall name them Eaſt and Weſt; the one on the left mark'd *E*, the other on the right mark'd *W*; and the Line that joins them, or that encompaſſes the Globe at an even Diſtance from *P* and *NZ*, let it be call'd the Horizon. Being, as I am now, at the Point *P*, which is the Centre of my Horizon; if the Sun was over my Head, the half of the Earth, which it would enlighten, would exactly be that, which is terminated by the Line of my Horizon; and the inferior Hemiſphere would remain totally darken'd. Now that the Sun is riſing, it is at the Point *E*, and remote from *P* by a whole Quarter of a Globe. The Half it lights, being the Width of two Quadrants, exactly terminates at *P* on the one Hand, and at *NZ*, which is near our *Antipodes*, on the other. Being at *P*, I then am on the Border of that Half, which the Sun enlightens. Its immediate Light ends and dies at my Feet, and at that Moment I can reach no farther. The Sun would otherwiſe light more than one Half of the Globe. The Border of the enlighten'd Half forms a Line that divides my Horizon into two Parts; that on the Left, towards *E*, is wholly enlighten'd; the other, on the Right towards *W*, muſt neceſſarily be totally dark; ſo that at that Moment my Abode ſhould be partly black, partly white. As the Sun ſhall aſcend, the Line, which ſeparates Night from Day, ſhall incline farther towards the Right *W*, and there ſucceſſively ſhew me new Objects. But when the Sun ſhall have got over the Point, at which it gives me Mid-day, the more it ſhall decline to the Right *W*, the more the Half it lights will be engaged under the lower Hemiſphere toward *NZ*, and the left Side of my Horizon ſhall ſoon be cover'd by a horrid Darkneſs, that ſhall, till Sun-ſet, increaſe ſo as to take from me the Sight of one whole Half of the Horizon. But at the very Moment of its getting under the Horizon, all the Light I enjoy'd from the Point *P*, or from my Feet to *W*, ſhall on a ſudden be taken from me, ſince it can no longer reach to me. This muſt be a neceſſary Conſequence of the immediate Irradiation of the Sun on the Earth. Why then does it not happen ſo? If I freely enjoy the whole Compaſs of my Horizon, not only when the Sun has once glanced upon the Borders of it, but even a great while before it arrives thereat, and a long Time after it has withdrawn from it; if the leaſt Portion I can have of its Light is eaſily diſtributed through my whole Habitation; to what am I indebted for ſuch a Favour? Is it to the Sun? No. This can never enlighten more than what it ſees, and there is no one Inſtant, at which it ſees more than one Half of the Globe. Is it to the Nature of Light itſelf? Not at all. Its Impulſion is direct, and can light nothing in thoſe Meanders, into which it penetrates not directly. The Atmoſphere, which is placed between the Sun and the Earth, does alone produce this noble Work. It no ſooner can bend the leaſt Portion of the Rays of the Sun on one Horizon, but it overſpreads that Horizon with it. When the Sun itſelf arrives at that Circle, the Atmoſphere prevents its Light's being divided there by fourths or thirds, or, as it were, ſparingly diſtributed. It amplifies its Utilities. It is commiſſion'd to improve its Favours, and not to ſuffer in any Part of the Garment, wherewith it cloaths the Earth, the unpleaſant and diſcordant Sortment of the Night and the Day, drawn near and patch'd up together.

The Sun and the Atmoſphere do then act in Concert for Man; and theſe two wonderful Inſtruments, though ſeveral Millions of Leagues diſtant from each other, mutually, and with a kind of Intelligence, aſſiſt one another in the Diſtribution of the Day. Here you have no Attraction, nor Gravity, nor any phyſical Cauſe that may have produced ſuch a Work. Certain particular Laws might maintain, but never could have effected it. The Frame and Diſpoſition of both theſe Pieces, ſo evidently made for each other, are owing to the ſame free Will that placed Man within the Reach, Uſe, and Benefit of them.

We have already perceived the expreſs and evident Will of God, in the Union of the Sperm and the Proviſion of the firſt Food, under the ſmall Cover of the Egg of a Mite, or that of a Hand-worm. We found an expreſs and particular Will and Determination, not only in the Structure of each Plant, but even in every the minuteſt Seed thereof. We find again the Character and Marks of an expreſs Will, full of Tenderneſs towards us in all the numberleſs Bleſſings, which God multiplies from Year to Year, and from Day to Day, both upon and within the Earth. But with what Splendor and Magnificence does that Will ſhew itſelf in the Beauty of the Sun, and in the juſt Proportion of Size, Diſtance, Action, and Uſefulneſs, that has been eſtabliſh'd between that Star and the Earth.

God ſeems, without ſhewing himſelf as yet, with great Care to have gather'd in that fine Star all the Strokes that might beſt repreſent the divine Perfections to us. Like God, it is ſingle. The grandeſt and moſt glorious Objects ſeem to dwindle and vaniſh in its Preſence. It ſees all. It acts through all. It gives Life to all. Thus, after the Earth has, in an infinite Combination of Manners teſtified and demonſtrated that Wiſdom, which for our Sake did ſo liberally enrich all and every one of the Parts thereof, the ſame Wiſdom ſtill breaks out in the Heavens with an infinitely greater Majeſty.

Pſ. xix. The Heavens, more eſpecially, declare the Grandeur and Glory of God. Nothing is more proper than the Firmament, to manifeſt God in his own Handy-work. Each Day commiſſions the following to declare God to us. Every Night leaves to the following the Care of preaching our Maker to us. The Inſtructions, which the Heavens afford us, are a Speech or Language no way barbarous or foreign to us. They are not weak Sounds difficult to be heard. The Voice of the Heavens is familiar and intelligible. It is ſtrong, ſonorous, and unwearied. It reaches from the Heavens to the Earth. It is convey'd from one End of the World to the other. There is no Nation, nor any Man on Earth, which does not underſtand it; and thus is the whole Univerſe inſtructed.

But the Sun alone teaches us better, and affects us much more, than all the Beauties the Heavens can diſplay to our Sight. The Heavens are merely like a Pavilion * to the Sun. The Veils richly embroider'd, which ſeem'd to take from us the Sight of that Star, are removed when it advances towards us. They are drawn, and he alone remains viſible. He is as a young Bridegroom coming out
of

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* Hebr. *Soli poſuit tentorium in illis (cœlis).*

of his nuptial Chamber, to ſhew himſelf on the ſolemneſt Day of his Life. His Splendor is then full of Mildneſs. All admire him at his Arrival. All Eyes are fix'd on him; and he makes himſelf eaſy of Acceſs to them all, in order to receive their firſt Salutations. But he is commiſſion'd to convey the Heat and the Life, as well as the Light, every where. He haſtens to diſcharge this important Office. He darts more and more Fires as he aſcends. He paſſes from one End of the Heaven to the other, and runs his Race like a ſtrong and indefatigable Wreſtler. He enlivens whatever he lights. There is nothing that can either be hid from his Light, or ſubſiſt without his Heat; and by his penetrating Fires he reaches thoſe very Places, which are inacceſſible to his Rays.

THE PROPAGATION OF LIGHT.

DIALOGUE VII.

THE Operations of the Sun may be reduced to three. It enlightens; it colours; it heats. It ſucceſſively lights the whole Earth, that Man, and the Animals, which ſerve him, may walk in the Light of that Flambeau, when it caſts it on them, and go and take their Reſt when it hides itſelf, and no longer gives them Light. It not only enlightens, but alſo colours the Objects. It diſtinguiſhes them, ſo that they may be known without any Confuſion, Diſpute, or Delay. In ſhort, the Sun, beſides procuring Light and Colours for us, does moreover convey Heat and Motion every where, in order to enliven Man, and perpetuate all the Supports of Life, which have been placed near him, both without the Earth, and within it's Bowels.

We

The Nature of the Light.

We mean not here to mention the more or leſs lively Sentiments, which we experience from the Preſence of the Sun, or of a great Fire. This, like all other Impreſſions, can no where exiſt but within ourſelves. It is conſtantly dependent on what ſtrikes our Eyes. But theſe are two different Things, one of which is a Conſequence of the other. The ſame Senſation may ſubſiſt within us during our very Sleep, and independent of any outward Impreſſions. Our Searches run only and ſolely on corporeal Light; on that Subſtance, which affects our Eyes, and whoſe Impreſſion is follow'd by another, which affects the Soul, and informs us of the Preſence, Diſpoſition, and Form of Objects. The Grounds of that Light wherewith God influences our Souls, and that of the Light, which affects our Eyes, ſeem to me equally ſuperior to our preſent Underſtanding. But as God is pleaſed to let us know, at leaſt by inward Senſe, a Multitude of Truths concerning the Nature of our Souls, and it's Affections, without granting us the Knowledge of all the reſt; he likewiſe is pleaſed to ſhew us a Part of the Workmanſhip, wherewith He for our ſakes puts the outward Light in Motion. Let us then eagerly lay hold of what we are allow'd to know of it. Our true Happineſs, even in this preſent Life, is to become grateful, in Proportion as we advance in the Knowledge of God's Ways. What then ſhall we be, when we ſee Light in the Boſom of Light itſelf?

Nothing is plainer, nothing more agreeable to Scripture, to the Hiſtory of the Creation, to Reaſon and Experience, than to look upon Light as an intermediate Fluid, which not only extends from the Sun to us, but alſo fills the whole Univerſe, and without changing it's Place by a ſucceſſive, though extremely ſwift Preſſure, conveys the Action of our Sun to the very Spheres of the Stars, as that Fluid tranſmits the Impreſſion and Sight of the Stars themſelves in the Sun's Sphere.

The Wave of a River communicates, to a great Diſtance, a ſingle Impulſion, or one ſeveral times reiterated. The Undulations of the Air carry ſtill quicker, and in all Directions, the Motion cauſed in the ſaid Air. From theſe Examples every one will eaſily believe, that a thinner, lighter and more active Fluid, (let the Nature of Fluids in general be what it will) may in a few Minutes convey the Impulſion of the ſolar Matter, which preſſes it very far, and render the Preſence and Influence of that Star ſenſible at prodigious Diſtances.

The Body of Light, conceived as an immenſe Liquid, always ſurrounds us, but is not always puſh'd down to us. It is only conſtantly ready to ſerve and inform us, at the very firſt Shock it ſhall receive from the Sun, from a Conflagration, a Flambeau, or a ſingle Spark. That Fluid is, indeed, puſh'd by the Sun, and by all inflamed Bodies, but is neither the Reſult or the Effect thereof. The Light then may have been created before the Sun, and the Stars have been as it were immerſed in it in ſuch particular Situations, as to make them correſpond by the Communication of the Motions they cauſe therein. Thus all the Spheres are involved in Light. There they ſwim or roll according to the Lines preſcribed and appointed them. The Light retains them all in their Places, and makes them viſible and uſeful to each other. Shall we then wonder at *Moſes* beginning the Recital of God's Works from the Creation of the Body of the Light, of that immenſe and equally precious Subſtance, in which the Spheres were to make their daily and annual Revolutions, and which was to be the Baſis, or rather the Bond, of all the Parts of the Univerſe?

But might we not have ſome reaſonable Conjecture on the Nature of Fluids founded on Experience; ſo that by the Application, which might be made of it to Light, the Underſtanding of the Effects it produces might be render'd eaſy and intelligible to us?

The Nature of Fluids.

It is plainly remark'd of all Fluids, as Water, Oil, melted Metals, and others; Firſt, That all the Parts thereof are incoherent; that they eaſily roll one over another, and are always ready to yield to the firſt Impreſſion. Secondly, That all theſe Parts have a certain, either inherent or borrow'd, Activity, which cauſes them mutually to preſs each other every way, as if they were ſo many ſmall circular Springs, always inclined to dilate or fly out on all Parts; ſo that as much as one puſhes the

the other, by ſo much it is reciprocally puſh'd thereby; the Force of each of which being equal, they counterbalance each other, and remain all in a perfect Equilibrio.

This ſecond Property of Fluids is the moſt eſſential. It is that, which diſtinguiſhes them. A Heap of Corn, or of Sand, as well as one of Water, is made up of ſeparate Parts, which eaſily yield to all Impreſſions. They, nevertheleſs, are no Fluids; becauſe the Parts, of which they conſiſt, have no ſort of Activity to preſs each other every way. Do you force your Hand into a Buſhel of Corn or Sand; the Grains are removed on each Side. They have a certain Gravity, which precipitates them downwards, ſo long as they are not ſupported; but they no ſooner reſt one upon another ſhelving as it were, but they remain at Reſt, and have no Manner of Force again, to get into and fill the empty Place that has juſt been impreſs'd in the Maſs. It is otherwiſe with Fluids. If you put your Hand, or a Stick down into them, that will be a Preſſure and an extraneous Force, which comes more or leſs to diſcompoſe the Equilibrium of that Fluid. The firſt Parts that are preſs'd bear againſt thoſe that are next to them all round. Theſe having a Motion greater than before towards one certain Part, ſhare it with thoſe, which are farther off on the ſame Side. This Motion actually being, or always inclining to be, made in the way of a Vortex, communicates itſelf all round and every way; and this orbicular Communication extends very far, becauſe one Particle impels two others next to it. Theſe two ſtrike againſt four that are more remote, and the four puſh the eight that follow. What we ſee done on one Side is at the ſame Time done on all others; and thus the Equilibrium of the whole fluid Maſs is diſcompoſed by a ſingle extraneous Shock. But this Diſcompoſure always leſſens in Proportion as the Number of the Particles, among which it is divided, does increaſe. On the other Hand, the natural Activity of thoſe Particles, (all which I for a Moment ſuppoſe to have a Spring acting every way) meeting with a Reſiſtance ſtill greater and greater, and leſs Liberty on the Side towards which they are puſh'd, they are immediately repell'd by others, and repreſs'd themſelves, both by their own Elaſticity, and by the contrary Efforts of the whole fluid Maſs tending towards that Place, from which they were firſt removed.

But how ſhall we conceive that the Particles of a Fluid have a Spring acting every way? If they tend one way, it is progreſſively. How then is it poſſible they ſhould tend towards the oppoſite, and every other Side at the ſame Time? So ſoon as they are puſh'd towards one Place, muſt they not of courſe recede from all the reſt? Father *Malbranche* [*] has ſupplied us for that Purpoſe with Mechanics, very plain and agreeable to the Action of all Fluids; *viz.* [†] To conceive all their Particles, as being ſo many ſmall Vortices perpetually rolling on their own Axes, and made up of other Particles, that endeavour, in circulating, to deviate from their common Centre. It would not be ſufficient with Mr. *Des Cartes*, to conceive the Parts of a Fluid, and thoſe of Light in particular, as ſo many ſmall Globes, or as hard and inflexible Whirligigs, lightly circulating on their own Axes. Theſe being inflexible, and without any Elaſticity, would likewiſe have no manner of Influence on each other; becauſe the Particles, of which they are compoſed, are at Reſt among themſelves, and ſtrive not to ſeparate. Lines made up of theſe hard Globules rank'd together, would be like a Stick, which being ſtruck at one End, at the ſame Time is ſtruck at the other. And this is contrary to Experience, which ſhews, that the Progreſſion of Liquids and of Light is ſucceſſive; whereas, if theſe Globules of Air, of Fire, or of Light, are themſelves made up of other incoherent Particles perpetually whirling round an Axis or a Line that may be imagined in them; it will be an eaſy Matter to conceive, how theſe Spherules mutually puſh each other, in ſtriving to dilate themſelves, and to widen every way.

Experience ſhews, that any moved Body has always a Tendency to advance in a ſtrait Line, unleſs it be diverted and driven aſide; and never follows a circular Line, but from the Conſtraint put upon it by the ſurrounding Bodies, which perpetually force it out of the direct Line. This may be proved by two Inſtances. When a Child puts a

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[*] See La Recherche de la Verite. Vol. IV. Eccl. 16.

[†] See the Phyſical Lectures of Mr. Privat de Molieres.

Stone in a Sling, he no ſooner ſets it in motion, but it ſhall perpetually endeavour to fly off from the Hand that gives it Motion. It ſhall inceſſantly, and with very great Force, puſh againſt the Bottom of the Sling. It will ſtretch the Strings; and ſo ſoon as one of them is let go, the Stone will get away in a Line, which would be ſtrait, did not Gravity perpetually alter the Direction thereof.

When a Singing-boy puts Fire into his Cenſer; as ſoon as the Machine with the Coals are in Motion, inſtead of falling through the Holes or on the Cover, which is often in ſwinging turn'd downwards, they on the contrary tend upwards, when the Cenſer riſes; they preſs againſt the Bottom of it, and perpetually endeavour to recede from the Hand, which is the Cauſe and Centre of their Motion.

If then the Particles, of which the Globules of a Liquid conſiſt, have all an Inclination to recede from their Centre, they ſhall be moved circularly for want of Power to follow the ſtrait Line, by reaſon of the mutual Obſtacle they are to each other. They will perpetually endeavour to part from, and mutually ſtrike againſt one another. From the mutual Preſſure, and the Equality of the Force of all theſe Globules, muſt needs follow an univerſal Equilibrium among them. Hence proceeds the orbicular Impreſſion of every Motion that chances to trouble that equal Balance. Hence the Reſiſtance of the whole fluid Maſs. Hence it's returning towards the Place from whence any of it's Particles have been removed.

Thus we may eaſily conceive, why a Drop of Water, Mercury, melted Gold, or any other Liquid, always takes a ſpherical Form. All the Particles of that Drop have an Inclination to recede from each other; but the equal Preſſure of the encompaſſing Air detains and forces them to move in a circular Line; therefore it is they gather in Form of a Ball. Hence we underſtand, why two Drops of Liquor no ſooner touch each other, but they gather in a ſingle Drop. Though theſe two Drops ſhould touch one another only in a ſingle Point, they preſently would become flat, and preſs each other in that Point. Herein the Circulation of the Globules is broken and conſtrain'd. They therefore endeavour to recover the Freedom and Action of their Spring. Their Action is not direct, becauſe they meet with a Reſiſtance in the Thickneſs of the Drop, not to be overcome; whereas they are leſs reſiſted towards the Intervals that ſtill ſeparate the two Drops a ſmall Matter. All the confined Globules ſhall then tend towards theſe empty Spaces, where they find leaſt Reſiſtance. They ſhall at laſt fill them ſo, that the Motion, which is univerſal in the two Drops, ſhall be made in a circular and uniform Manner, by the circular gathering of the two Bodies into a ſingle one.

Thence we may conceive, that as a Veſſel preſſes on the liquid Maſs, which is under it, thus all the Globules of the Liquid preſs, and reciprocally act againſt the Veſſel; and this floats on that without ſinking, when the Force, which makes the Veſſel heavy, and that of the reſiſting Liquids, are equal and in Equilibrio. We may in the ſame manner conceive the Reaſon of the Rarefactions or Dilatations of a Fluid, as of boiling Water or Coffee, or of frothing Wine. There is another more active Fluid, as Air or Fire, which has inſinuated itſelf into the Interſtices of the Globules of the firſt, and ſuſtains or even diſperſes them by the Superiority of it's Force.

Thence again may be deduced the Reaſon of the Diſſolutions, Ebullition, and Effervescences, that happen by the Mixtures of ſome cold Liquors, Salts, and other Matters. The Activity of the Vortices is different in every liquid Body. The Exceſs of the Strength of ſome over that of others may therein occaſion a Tumult, that will leſſen in Proportion as the whole Maſs ſhall come near to an Equilibrium; and the Activity, which is inſeparable ſome them, ſhall render them capable of ſeparating from Salts or certain Metals, and of ſuſtaining a certain Quantity of them on the Circumference of their Globules.

Now, if we apply this Structure of Fluids to the Light, we may conjecture, that the Matter, of which the Sun is made, being the moſt active of Bodies, that large Globe, by revolving on its own Axis, and endeavouring to dilate itſelf on every Side, or perhaps in darting its Flames from the Centre to the Circumference, and bringing them back again from the Circumference to the Centre, ſhocks, ſtrikes againſt, and perpetually ſcatters on every Side the vaſt Fluid of Light, which ſurrounds it; and that the Strokes, which the Light receives from it, are felt at the very Spheres of the Stars; making thus on all Sides, an unconceivably ſwift, though ſucceſſive Undulation. We eaſily conceive, that the Force of that Preſſure always leſſens in Proportion to the Diſtance; and conſequently, that the Light acts much more powerfully on the Planets nearer to the Sun, than on thoſe that are more remote therefrom; and finally, that the univerſal Reſiſtance of the Fluid, to the Strokes of the ſolar Fires, makes it perpetually flow back towards the Sun, that continually puſhes and is reciprocally puſh'd by it; which keeps the Sun in the ſame Place, and hinders it from waſting.

Sure there is in the Structure, as well as in the Action of thoſe Fluids, an Artifice infinitely ſuperior to theſe poor Conjectures. But they nevertheleſs help us in ſome little Meaſure, to be conſcious of a Truth equally affecting and certain; *viz.* That if theſe Powers, inſtead of mutually deſtroying each other by their terrible Claſhings, do on the contrary preſerve, maintain, and counterbalance, each other, in a Manner, which conveys Order and Beauty every where; of courſe there is not one ſingle Particle in thoſe Fluids, but what has been weigh'd in a Balance in order to proportion and adapt its Shape to the adjacent Particles. There is none but what has received a determined Form; none that has not received its exact and preciſe Meaſure of Activity.

The Shape of the Globules, or Atoms of Light.

Now let us ſee what the Maſs or Bigneſs of an Atom or Globule of Light can be. The Creator having deſign'd to take the Dimenſions of it, what we may conceive thereof, well deſerve that we ſhould beſtow a little of our Attention upon it. You eaſily judge of the Difference there is between the Body of the Air and that of the Water, from the Difference of their Waves; and as the Vibrations of the Air or Sounds are communicated ſeveral hundred times quicker than the like Agitations of the Water; we thence conceive, that Air is ſeveral hundred times thinner and more active than Water. If then Light, as Experience ſhews, croſſes a Space of ſix hundred thouſand Leagues almoſt as quickly as Sound traverſes over two or three thouſand Fathom; the Globules of Light muſt needs be ſix hundred thouſand times finer and more active than a Particle of Air, which nevertheleſs eſcapes our Sight, though aſſiſted by the beſt Microſcopes.

But let us leave off Calculations always tireſome, and oftentimes uncertain. We have a much plainer Method for meaſuring a Particle of Light. Obſerve in the Microſcope one of thoſe Animals, which are found in Water in Summer-time, after one has infuſed Pepper therein, or Flour, or any Plant whatever. In a few Days, the Eggs of thoſe Inſects are hatched therein, ſome of them being already on the Plants or Fruits put in the ſaid Water to be diſſolved, and others being laid in the Water by the Mother, which ſearches in the Air, and by the Help of ſmelling, for a proper Place to lay them in. Theſe minute Worms are very often a thouſand times ſmaller than the moſt imperceptible Mite; ſince the Microſcope ſhews us thouſands of them in a Drop of Water, which is ſmaller than the minuteſt Grain of Sand. What can be the Size of ſuch an Animal? What the ſeveral Fluids, of which his Eye is made? What will the foreſhorten'd Image of the Objects repreſented in the Bottom of ſuch an Eye be? Now that Image is made up of the Extremities of an infinite Number of Rays of Light. What then can be one Globule of that Light? And if each Globule is a Vortex made up of ſmall Particles, which all have an Inclination to diſtend themſelves every way, and which loſing a little of their Equilibrium by an extraneous Preſſure, cauſe at the Bottom of the Eye of that living Creature a Vibration proportion'd to its peculiar Wants, this ſhall be an Abyſs of Diminutions in the Shapes of Elements, as well as in thoſe of compound Bodies. It ſhall again be an Abyſs of Proportions in the Motions that are leaſt underſtood, and of Wonders in what is hidden as well as in what is perceived.

How much ſoever beyond the Reach of our Senſes the Structure and Dimenſions of the ſmall Particles of Light may be; yet may we make ſome tolerable Judgment of it, by comparing its Action and Effects with thoſe of ſome more perceptible Elements. There are indeed in God's Works Differences that characterize them all. But there is at the ſame time a Ground of Analogy, which intimates the Unity of the Artificer. What a Variety is there in Animals? Nevertheleſs, they all have a Heart, a Quantity of Blood, a Stomach, Lungs, or Parts equivalent? What a Variety in Plants? Yet all have a Seed and Farinæ, or vivifying Duſts, to make thoſe Seeds fruitful. All animated or living Bodies differ in ſome particular. But at the ſame time they all agree at bottom, by ſome kind of Reſemblance; and wherever that is wanting, we judge, and are ſure, that it is no longer a living Creature that we behold. We therefore are in the way of Truth, when obſerving Light to act in the manner of Fluids, we ſuppoſe it to have at bottom a Reſemblance with other Fluids. And as nothing as yet ſeem'd more proper to account for the Equilibrium of Liquors, than to conſider their Particles as ſo many Globules, which mutually preſs each other, by the Equality of the Efforts, which each individual Particle of thoſe Globules makes, in order to recede from the Centre, round which they revolve; by this Means we may frame to ourſelves a Notion of the Nature of Light, and thence deduce the Manner, in which it is communicated.

If you put a Wall, or any other groſs Body, in the way of Sound or Air agitated by the Voice, the Air is ſtop'd and there reflected. If you oppoſe a Wall, arch'd according to certain Rules, to the Sound of an Inſtrument, ſeveral Lines of Air that ſhall be reflected from the ſeveral Points of that Bend, may meet in one and in the ſame Point; ſo that the Ear, being exactly at that Point, ſhall hear eight or ten Violins inſtead of one *. The Wave, that is form'd on the Surface of the Water of a Pond, meeting a Pier, Bank, or any other Obſtacle, is ſtop'd ſhort there. It then ſhrinks back, and retires on itſelf, and the Portion of its Circle, which remains imperfect, and as it were cut by the Bank or Pier, is compleated on this Side, and in a contrary Direction, though in a weaker Degree occaſion'd by the Reſiſtance of

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* The ſame Thing may be obſerved in the Court before the Caſtle of Geanete, a Place two Leagues diſtant from Roan, in Caux.

of the Wall whence it is reflected. The Emotion of the Air and the Water communicates itſelf a ſmall Matter into the Windings, and behind the Bodies oppoſed to the direct Line; but this Emotion being diverted and changing its Direction, ſoon after becomes inſenſible. In ſhort, every Fluid, which receives any Impulſe or outward Preſſure, loſes thereby a Part of its Equilibrium, and the Agitation cauſed therein is diſtributed through the whole Maſs radiating on every Side. But as the ſaid Agitation is, as it were, more ſtrongly felt by the Particles, which are firſt moved, and always leſs and leſs by thoſe that are the remoteſt, the Communication of that Impreſſion at firſt is ſtronger, then weaker, and diminiſhes in Proportion to the Degree of their Remoteneſs. Nay, if ſeveral Motions are at once given to the Fluid; if you give it ſeveral reiterated Blows, and in contrary Directions; all theſe Waves will perhaps interſect and mutually weaken each other, but never be blended or totally deſtroy'd. All the Noiſes and Cries of any publick Place reach the Ears of all thoſe that live near it, and all the Voices, whether ſtrong or weak, in a Concert, ſtrike the Ears of every Liſtener. But the moſt predominating of them is always diſtinguiſh'd, as the briskeſt Bow of the Concert is heard above the reſt. The very ſmalleſt Impulſe cauſed in the Water of a River ſhall regularly be diſtributed all around, and the largeſt Waves ſhall not be a whit more real for their being better perceived.

Thus the fluid Body of the Light being (though in an infinitely more active and ſwifter manner) ſtruck by the enormous Shocks of the Sun whirling on its own Axis, receives from it ſuch an Agitation, as reaches to the very Spheres of the Stars. But to the End that this Fluid may appear there, what a Star appears here below; that is, to the End that one Stroke of the Sun may carry its Impreſſion far beyond ſeveral thouſands of Millions of Leagues, the firſt Motion of ſuch a Wave muſt needs be of an unconceivable Violence near the Body of the Sun. This Motion of the Light, compared to the higher Billows of the Sea, muſt needs be what the foaming Sea itſelf is, in compariſon of a Pond, whoſe Surface rimples under the Breath of the gentleſt Zephyr.

But here I am greatly miſtaken. The ſlight Depth of the Ridges, which that gentle Breeze has impreſs'd on the Water of the Pond, and the Height of the Surges, which the Sea toſſes on high, may be meaſured and compared together. But when we are to meaſure the Diſtance between the Sun and a Star, or to calculate the proportional Decreaſes of the Light from the very Beginning of its Waves, to the Places where they ceaſe to act; it is then that Geometry and Arithmetick fail us. But then theſe were given us to meaſure round us the Things merely that bear any Relation to us, the Proportions and Limits whereof may be found.

This conjectural Explanation of the Nature of Light is methinks the more delightful, becauſe it is grounded upon the uniform Conduct, which God has obſerved in the Action of all Fluids. It is agreeable to the Effects of the Light; and nothing ſeems to me more capable of rectifying the Miſtakes we almoſt all of us fall into, on the Nature of that wonderful Element.

We have, in our Infancy, contracted a falſe Notion of the Light, which we have much ado to get rid of in an advanced Age. As we ſee Objects, without perceiving any thing between them and us; the whole Interval, which ſeparates us and them, appears to be nothing but a vaſt Vacuum, and we fancy that our Eyes have of themſelves the Power of ſeeing what is before us, without the Neceſſity of having any Body to be puſh'd or reflected from theſe Objects toward our Eyes. Much leſs do we ſuſpect that Space to be fill'd with a Subſtance ſufficiently active, to be reflected from every Object towards all the Eyes that ſhall offer, fine enough to penetrate through them, and diſtributed, as it enters them, with a Regularity ſufficient to form any Picture therein. But though this Error be but of ſmall Conſequence; yet the Intention of him, who created the Light, not being that every one of us ſhould inquire into the Nature of it; but rather, that we ſhould uſe it with Gratitude; yet when we ſit down to review our firſt Notions, and endeavour to judge of Things as rightly as we can, then have we a thouſand Ways to correct this innocent Miſtake.

We naturally, and without the Help of much Reflection, are preſently convinced of the Exiſtence of the Air; and we acknowledge the Reality of it, becauſe we hear the Noiſe and feel the Impulſes thereof; though an infinitely wiſe Oeconomiſt has placed beyond the Reach of our Sight the Particles of the Air, which ſurround us. So is it with the Body of the Light, which, though incomparably finer, yet is it not a whit the leſs eaſy to know, with full Certainty, the Preſence and Extent and Properties of it; ſince the Difference of its Way through the Air and the Water may be diſcern'd, and ſince we can exactly mark the ſeveral Points, which the Light ſhall arrive at, in paſſing through a triangular Priſm, or a hollow Glaſs, or through a lenticular Maſs of the ſame Matter. Pray, don't you think, that our diſtinguiſhing the Motions of the Light, our making uſe of its ſeveral Progreſſions, and our preſcribing even the exact Point whereon we would have it fall, is to us a great Aſſurance that it exiſts round us, and is at our Command?

Another Miſtake, which we have already prevented, is, to believe that the Light reaches us by a local Motion, or by its real falling on the Objects, and on the Eye; ſo that the Rays, which, for Inſtance, make me diſcern (when I am on *Pont-royal*) the Figure of King *Henry* IV. on Horſeback in the Middle of the *Pont-neuf*, muſt have croſs'd the whole Space between the Sun and the ſaid Figure, and then by a ſecond Tranſportation muſt have reach'd my Eyes from Bridge to Bridge.

No. The Thing is quite otherwiſe effected. We live in the Fluid of the Light, as Fiſhes do in Water. When nothing agitates the Water, the Fiſh never feel it. So, when nothing agitates the Light, neither do we feel it. But how comes it, that the Fall of the Net, which a Fiſherman has juſt caſt, has put to flight a Fiſh, which was far enough from it? Have thoſe Parts of the Water, which the Fiſher has ſtruck, been tranſported from Place to Place as far as the Fiſh? Not in the leaſt. But the Preſſure on theſe, has deſtroy'd the Equilibrium of thoſe that were more remote. Theſe again have ſtruck againſt the following, which have ſhock'd others; and the News of the Danger has thus reach'd the Fiſh, not by the

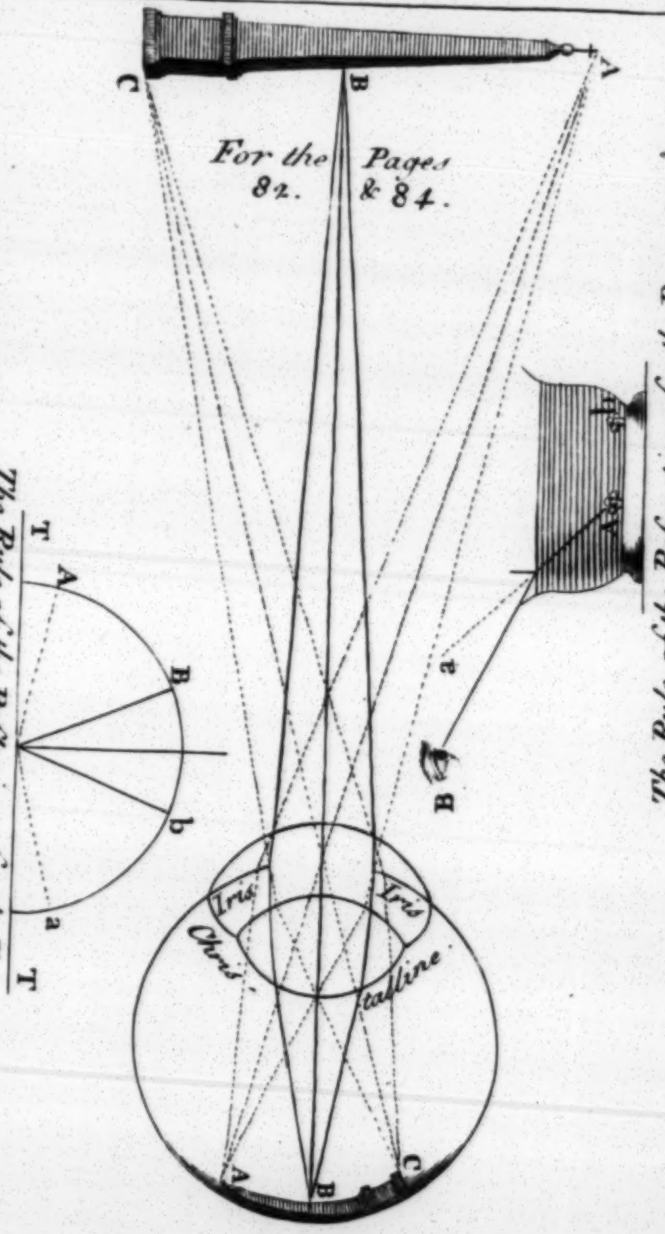
Tranſportation, but by the Preſſure of the Particles of the Water. When therefore we ſay, that from the whole Maſs of the Atmoſphere, a Multitude of Rays of Light fall on the Head of King *Henry* IV, and that theſe Rays, which come upon it from all Sides, daſhing every way therefrom, croſs the Air, and traverſe the Eyes of the Spectator, it is an improper and incorrect way of ſpeaking, authorized however by Uſe, and which being reduced to exact Truth, muſt be underſtood of a quick, though ſucceſſive, Preſſure made in the Fluid, without having the Parts of it conſiderably diſplaced; and this Diſplacing is leſs in Proportion as the Remoteneſs of the luminous Body is greater; juſt as we ſee the Water ſtrongly agitated under the Oar of the Waterman, who moves it, which a great way off finds but a gentle Shock, leſſening every Moment. It is by theſe Lines of Preſſure, either immediately proceeding from the luminous Bodies, or reflected from the Objects, that we maintain a Correſpondence with what is about us upon Earth. By the Help of theſe Lines puſh'd from above, and reflected from the Point of a Needle, as well as from any Platform, twelve, or even a hundred People, ſhall be able to perceive the ſame Point, from ſeveral Places, at one and the ſame Time. It is by ſuch Lines that we have a Correſpondence with the Stars, and with the whole Heaven. The Activity of that Preſſure, which has its Original either in the Stars, or in ſome flaming Body, is diſtributed into large Waves, which are cut by all the Points of every Object that happens to croſs their Paſſage. The Proportion of that Wave, which is reflected on a Point, is communicated round about, and as it were unravell'd into other ſmall Rays, each whereof meeting with ſome new Object, ſuffers a new Diviſion. All theſe Reflections and Attenuations are ſenſible in the Light, and convince us of its perpetual Preſence, and of its extreme Mobility. It ſubſiſts always the ſame. But the Preſſures it has undergone always leſſen from one Reflexion to another, by new Subdiviſions, as from *A* to *B*, from *B* to *C*. and when at laſt it is reſtored to its State of Equilibrium, it has then no longer any Influence over us. It ſurrounds without ſtriking us, and is nothing but Darkneſs.

THE WAYS of the LIGHT, AND THE WONDERS of VISION.

DIALOGUE VIII.

HAVING thus made the requiſite Diſtinction between the Impulſion of the Fire of the Sun, and the Activity and Spring of the vaſt Fluid of the Light; let us now unite what we before divided; let us now make them concur, and for the future look upon theſe two as one ſingle Agent, whoſe ſeveral Impulſes, acting every way in ſtrait Lines, may be properly diſtinguiſh'd by the Name of Rays.

All theſe Strokes rapidly continue, and for ever repeat the ſame Rout towards the Extremities of the Sphere. They even reach to the Spheres of the other Stars, but are attenuated in the Immenſity of the Spaces they go through, and at laſt are extinguiſh'd or abſorb'd by the ſuperior Impulſion of thoſe other luminous Bodies. If they meet with any maſſy Bodies that croſs the Lines of

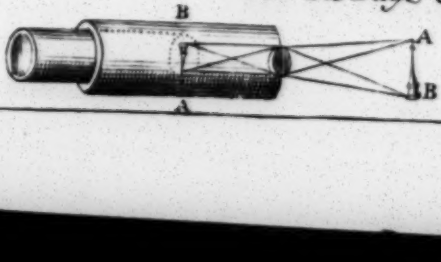


For the Pages 82. & 84.

The Rule of the Refractions for the Pages 73 & 75.

The Rule of the Reflexions for the Page 75.

For the Page 82



Ja. Mynde Sculp.

of their Directions, then it is, that theſe Rays produce the great Effects, for which the Creator inceſſantly ſend them; for they either are reflected, that is, ſent back by theſe Bodies, and ſhew them us more or leſs luminous; or they pervade, paſs through, and render them tranſparent; or, in a Word, they are abſorbed by them, and loſe their Direction there; ſo that theſe Bodies remain in their natural State, that is, opaque or without Light.

The Reflexions of the Light.

There is no one Body, whether fluid or fix'd, that does not partly reflect, and partly admit the Light. All Bodies are made up of Parts divided by Pores, and of impenetrable Elements. All is not porous in them; and after the ſmalleſt Pores, which we ſhall call the laſt, there are of Neceſſity ſome ſolid Parts, that will ſtop the Paſſage of the Light. It then ſhall be partly admitted into certain Apertures, proportion'd to it's Size or Form, and partly ſtop'd by the ſolid Parts, on which it's Spring being preſs'd cannot but return. But it not only bounds on impenetrable Parts, it may be as much, and perhaps more abundantly, reflected by the Fluids, that may chance to be on the ſurfaces within the Pores and Interſtices, which divide the ſolid Parts. For Inſtance; if the Fire was a fluid Element diſtinguiſh'd from the Light (a Point, which I don't examine at preſent into) when lodged in maſſy Bodies, it would be very apt to cauſe Light to be reflected there, neceſſarily repelling one Spring by another. The Air, whoſe Elaſticity is ſo well known, may in it's turn contribute to the ſame Effect. The Water, the Oil, and the other Fluids, that are diſperſed through all Bodies, may as well, and perhaps better than the ſolid Elements, multiply the Reflexions of the Light; and the Benefit of that Reflexion conſiſts in it's rendering Bodies viſible to our Eyes.

The Refractions of the Light.

The moſt compact Bodies, ſuch as Salt, Cryſtal, and Diamonds, are wholly interſperſed with Pores, and every way admit ſo fine a Body as Light is. But whenever Light paſſes out of a ſolid Body, whoſe Particles are in Repoſe, into a Fluid, as Water, or into one elaſtic, as the Air, it changes it's Direction. The ſame happens, when it paſſes from a Fluid into a hard Body, or even from one Solid into another of a different Make and Structure. The Ray is there bent, and deviates more or leſs from it's Direction. This Bending is what they call Refraction; and to convince you of the Variety of the ways, which Light takes in paſſing through new Mediums, I ſhall propoſe to you no other than the two moſt common Inſtances, and thoſe moſt expoſed to every Eye. Pray, call to mind the Form, which a Stick half dipp'd into the Water aſſumes. It ſeems broken; becauſe the Rays that return from the immerſed Part of it, coming into the Air, follow not the ſame Direction they had in Water. You may likewiſe remember, that when you draw back from the Rim of a *China* Bowl, till you can no longer ſee the Flower-basket painted at the Bottom, in *A*, ſhould any one pour Water into the Bowl, though you do not change your Place, you then plainly ſee the Flower-basket, in *b*; and the Water can be no ſooner ſuck'd up with a Reed, but the Basket ſhall again diſappear. When the Water is gone, you ſee the Basket no longer; becauſe the Rays that go from it to the Borders of the Bowl, paſs above your Eye, in *a*; whereas, when the Water is in the Bowl, the Ray paſſing from the Water into the Air, bends and is lower'd ſo, that it meets not the Top of your Fore-head, as it did before, but your Eyes, which then perceive, in *B*, what is in reality hidden, with Regard to them, behind the Edges of the Bowl.

A Deſire of bringing the important Services of the Light to Perfection, has cauſed Men carefully to ſtudy the Reflexions and Refractions of it. They have explored all the Paths, and the moſt delicate Variations of it, and found out, either in the Boundings, or in the Bendings of the Light, Rules ſo conſtant and ſteady, that they have been made a moſt certain Science, and an Art productive of a thouſand uſeful Contrivances. To this Study we are beholden for the making and cutting of Looking-glaſſes, of Jewels, or of Glaſſes cut faced and table-wiſe, hollow, relievo, *&c.* of reflecting and refracting Teleſcopes, and of an amazing Multitude of other Inſtruments fit to aſſiſt Aſtronomers, and the common Uſe of Sight. As Optics is no leſs engaging, by the Clearneſs of it's Principles, than by the Excellency of it's Effects; I have it at heart, one Day or other, to collect for you the fineſt Parts of it. But the Order of our Diſcourſes obliges us, for the preſent, to be contented with the two Laws, which Light invariably follows, which are the Foundation of the moſt curious Things that can be ſaid about it, and of which we may be inform'd by the bare Teſtimony of our Senſes. The one belongs to Reflexion, and the other to Refraction. In both Caſes, an imaginary Line is ſuppoſed to fall perpendicularly on the Surface of the new Medium, into which the Light enters.

The Rule of Reflexions.

The Rule of Reflexions conſiſts in knowing, that the Light falling perpendicularly on a Surface, returns again from it in a perpendicular Line; but that, when it falls thereon obliquely, it bounds back from it on the contrary Side with the like Obliquity, from *B* to *b*, and from *A* to *a*; or, what is the ſame Thing, that the Angle of Reflexion is equal to the Angle of Incidence.

The Rule Refractions.

The Rule of Refractions conſiſts in knowing, Firſt, That the Light, which enters a Medium perpendicularly, ſuffers no Bending there, and proceeds onward according to the ſame Direction. Secondly, That when it paſſes obliquely from a rarer Medium into a denſer, it deviates a ſmall matter from this Obliquity, as it goes through the Body of the Medium, and inclines towards the Perpendicular. Thirdly, That when it paſſes from a groſſer or denſer Medium, into one that is leſs compact or more rare, as out of Glaſs or Water into the Air; it deviates from the Perpendicular, and inclines a little to the Surface of the lighter Medium. We ſhall perhaps one Day or other, look into the phyſical Reaſon of theſe two Rules, and the Reaſon why the Refraction of the Light is juſt the Reverſe of that of ſolid Bodies; for, a Stone obliquely thrown into the Water, deviates therein from the Perpendicular, inclining a little towards the Surface; whereas, when obliquely flung from the Water into the Air, it deviates a little from the Surface of the Water, inclining towards the Perpendicular. But all that can be imagined on the Reaſons of theſe Motions, will never be either ſo ſure or ſo ſatisfactory as theſe two Principles,

which

which are Matters of Fact. The Application of them takes in all that is ſufficient for us to know, in order to vary the Uſes of Light according to our Wants.

The Cauſe of Opacity.

Here the famous Queſtion of the Opacity of Bodies naturally offers itſelf. What can be the Cauſe thereof? It is already difficult enough to conceive, how a Body ſo hard and ſo compact as a Diamond is, is every where open to admit the Light. But it is much leſs conceivable, how a Wood ſo porous as Cork, is not a thouſand times more tranſparent than Cryſtal. It is no leſs perplexing to account, why Water and Oil, which both are tranſparent, ſingly taken, loſe their Tranſparency when they are beaten together; why Champaign wine, which is as bright as a Diamond, loſes it's Splendor, when the Bubbles of Air dilate, and raiſe a Froth therein; why Paper is opaque, ſo long as it has in it's Pores nothing but Air, which is naturally ſo clear, and the ſame Paper becomes tranſparent, when it's Pores are fill'd with Water or Oil.

The moſt Part of Men, and Philoſophers as well as the Vulgar, are of an Opinion, that a Body is opaque and dark, becauſe it does not admit the Light into it's Pores, and that this Light would appear therein, did it go through it. But let us renounce this Error. The firſt Elements excepted, of which Bodies are made, there is not perhaps a ſingle Body in Nature, but what is acceſſible to and penetrable by the Light. A Spherule of Air will yield a Paſſage to it, provided it does not enter it too obliquely. It goes through Water and other ſimple Fluids. It penetrates the ſmall Laminæ of Gold, Silver, and Copper, which are divided and ſufficiently attenuated, to be in Equilibrio with the corroſive Liquors, in which they are put to diſſolve. The Bodies, which appear the moſt ſimple to us, as Sand and Salt, are tranſparent. Even the Bodies, which are but a little compound, eaſily admit the Light, in proportion to the Uniformity and Repoſe of their Particles. Glaſs, Cryſtal, and, above all, Diamonds, are Compounds of hardly any thing but fine Sands, and of a few more or leſs fine Salts. Wherefore they are a very little Obſtacle to the Paſſage of Light. It is otherwiſe with a Spunge, a Slate, or a Piece of

Marble. All theſe Bodies, which we call opaque, when between the Sun and our Eyes, admit indeed the Light like ſo many Sieves; but they divert it, they blunt it, and ſenſibly hinder it from reaching our Eyes. What then is there in them, which can cauſe in the Light an Alteration it does not undergo in infinitely more compact Bodies? This Diſorder, if it be one, proceeds from the Variety of the Pores, and the Diverſity of the Principles, of which the Body is compounded. Recal to your Mind what we juſt advanced; that Light, when it falls on a Surface, partly goes through, and is partly reflected from it. Secondly, You know that it bends many different ways, in all the various Mediums it paſſes through. Let us begin to apply our two optical Rules. The firſt Benefit we ſhall thence receive, ſhall be a very plain Explanation of the Opacity of Bodies.

If a Body be made of Particles only uniform, as Water and Diamonds are, the Portion of Light admitted therein ſhall in an uniform Manner paſs through the Maſs of that Body. There are the ſame Particles every where, and every where the ſame Diſpoſition of Pores! That Path ſhall conſtantly be the ſame to the oppoſite Extremity, where the Light may afterwards ſenſibly come out.

But if the Body, which the Light enters into, is made of very diſſimilar Particles, ſuch as the Laminæ of Sand, of Lemon, Oil, Fire, Salt, and Air; the Globules and Laminæ of theſe Elements being of a different Denſity, and of different Situations, the Light bends and is reflected very variouſly on them. It deviates from the Perpendicular in entering into a Particle of Air, and inclines towards the Perpendicular when it enters into a Lamina of Salt. The ſeveral Obliquities of the Surfaces it enters from one Inſtant to another are a new Source of Meandrings and Attenuations. Even a Body's being bored with a vaſt Number of Holes in every Direction, is ſufficient to make it loſe it's Tranſparency. Jewels loſe theirs in a great meaſure; Fire makes a kind of Sieve of them; becauſe Light ſuffers there too many Reflections, and winds upon ſo many Surfaces all differently inclined; whence it happens, that it cannot in an uniform Manner go through and reach the Eyes of the Spectator.

Opacity proceeds then from the Diſorder of the Reflexions and from the windings of Light, occaſion'd by the too great Variety of Pores. Of this you have a well known Inſtance in Coals, in which Fire has form'd itſelf millions of Paſſages, which the Microſcope renders viſible. A Coal admits into it much more Light than the Diamond; but it diverts and abſorbs that Light in the Pores, and on the numberleſs Surfaces oppoſed to it, which break it within the Maſs, inſtead of reflecting it abundantly towards the exterior Surface, or of tranſmitting it, by a regular Track, to the oppoſite Extremity. Hence it appears, that there is no Body, that receives inwardly ſo much Light, and ſuffers ſo little of it to paſs orderly to the oppoſite Extremity, as the blackeſt and moſt burnt Bodies.

Opacity again proceeds from the Variety of the Tracks of the Light, cauſed by the Multiplicity of the elementary Laminæ, of which Bodies are made. All theſe Laminæ taken ſeparately are tranſparent; but when mix'd, they ſo variouſly bend the Light, that they deſtroy the Direction and Senſation of it. The ſame happens to the Oil and Water beaten together. It is likewiſe obſerved in Champaign-wine, when it is drawn from the Cellar, and the preſs'd Air it contains begins to feel the Heat and Communication of the external Air. It dilates and ſuſtains the Liquor on it's widening Globules; ſo that the Light bending perpetually, and in a manner quite different in the Laminæ of the Wine, and in the Bubbles of the Air, it can no longer make itſelf ſenſible through the Liquor.

It is the Variety of the Inclinations of the Surfaces, together with the Diverſity of the Refractions, which cauſe an Opacity in dry Paper, and in the unpoliſh'd Glaſs. The ſmall Intervals, which divide the Fibres of the Paper, are fill'd with Air. The Furrows, which have been imprinted on the Glaſs, either by rubbing it with Sand, or by grinding it, are ſo many hollow Places and Pits, which are are fill'd with Air. The Light, which, in paſſing from the Glaſs into the Air of theſe Furrows, has been bent therein, falls on the Borders of the ſaid hollow Places, whence it is reflected towards our Eyes; but then it ſhews us the Surface, which reflects it abundantly, inſtead of making the Glaſs appear tranſparent, in ſhewing us what is beyond that Surface. If you fill the Hollows of the furrow'd Glaſs, or the Pores of the Paper, with Oil or Water; the Light, in paſſing from the Laminæ of the Rays or Paper, or from thoſe of the Glaſs, into the Water, which fills the hollow Places, there inclines to the Perpendicular. It follows an almoſt uniform Way, both in theſe Laminæ, and in the Liquor. It is leſs turn'd out of it's way, than if it ſhould find thoſe Cavities full of Air; conſequently, a greater Number of Rays of Light thence reach to our Eyes.

From all thoſe Inſtances, you ſee, Sir, that there is not one Body, but what is naturally tranſparent; and it ceaſes to appear ſo, only when the Light is diverted or alter'd, either in the Irregularity of it's Pores, or the Variety of the Particles, eſpecially of the Fluids, which bend it in quite a different manner. And this is ſo very true, that if the moſt opaque Bodies, ſuch as Wood, or Marble, are reduced into very thin Laminæ; then the Light, having not as yet loſt it's firſt Direction, yields therein a ſmall Degree of Tranſparency. This may be remark'd in a very thin ivory or wooden Leaf of a Table-book, when applied to the Hole of a Window-ſhutter, through which alone the Light was admitted into a Room. It may be ſeen likewiſe in the Laminæ of Iſinglaſs or Talc, in Allum, in Alabaſter, and in many Stones, which being in their Nature leſs mix'd with different Principles than other Bodies, become tolerably tranſparent, when made thin, ſo as to become a kind of Glaſſes to us, which was very much in uſe among the Antients. Again, this may be agreeably remark'd in that fine and delicate Plait of the Robe of one of the three Graces, whom *Germain Pilon* has placed, in the Stead of the three Virtues, in the Chapel of *Orleans*, at the *Celeſtine* Monks of *Paris*, to ſupport the Urn deſign'd to receive the Heart of King *Henry* II. If the Spectator ſtands ſo as to have that fine Groupe between the Windows and his Eye; then the Marble is ſo artfully faſhion'd in the Drapery of one of the Figures, that it has the Tranſparency and Delicacy of Cloth.

After having, with a general View, conſider'd the Impulſion of the Sun on the Fluid of the Light; the Communication, which is made of it round about according to ſtrait Lines; the Weakening and Diminution of that Impulſion, when Light is reflected by the Occurrence of Bodies, and divided in proportion to the Number of the reflecting Surfaces; the Folds it ſuffers in tranſparent Mediums; and at laſt the vaniſhing of it in the Bodies, wherein it is diverted out of it's direct way, and which thereby become opaque; let us now trace it in the Eye. The Eye is the Goal where it is appointed to reſort; and for the Eye it was calculated.

The ſeveral Cauſes, which may either miſlead or weaken the Rays of Light, and hinder them from reaching our Eyes, are eaſily diſcern'd; but is it poſſible to know, what it's Operations are when it comes thither?

As Light is deſign'd to enlighten the Eye; the ſtructure of that noble Organ is entirely diſpoſed according to the Nature of Light; and it is becauſe this is bent ſeveral Ways, according to the Variety of the Mediums it paſſes through, that the Eye was divided into three Partitions, fill'd with three different Humours, and ſo diſpoſed, as to unite at the Bottom of the Eye the Rays, which, without that Artifice, could never arrive thither in good order. The Plan we have propoſed to ourſelves obliges us to defer to another Time the geometrical Meaſures of all theſe Tracks. But it is an eaſy matter, independently of this preciſe Exactneſs, to make you ſenſible of ſome Parts of the Wonders of Viſion.

The Eye is a natural Teleſcope, of the Form of a Ball, ſomewhat longiſh in the Fore-part, and which the Creator has ſuſpended by ſeveral Muſcles, to govern it according to our Occaſions. Theſe, as well as all other Muſcles, ſhorten as they widen, and lengthen when they contract. One is deſign'd to raiſe the Eye. A ſecond to lower it. Two others are appointed to bring it by Turns towards the Noſe and the Temple. A fifth, which ſlides within a cartilaginous Ring, like a Cord over a Pulley, and is faſten'd to the Globe of the Eye in two Points, makes it roll about at Pleaſure. A ſixth lies under the Eye, and is deſign'd with Comelineſs to temper and reſtrain within proper Bounds the Action of the reſt, which might otherwiſe be exceſſive and ſhocking. In ſhort, there are a Multitude of different Pieces of Mechaniſm, which artfully aſſiſt each other, to make the Eye advance forward, retire, and move every way; ſo that a ſingle Eye is to us as good as a thouſand, by the ſurpriſing Variety of it's Situations.

But the Action of a vaſt Number of different Springs is neceſſary, to open or ſhut the Eye, to make it advance or draw back, to widen or contract it's Orbit, in ſhort, to govern it according to the Exigency of Occurrences. Is it Man that governs the Motions of it? Is it the Eye itſelf that turns ſeaſonably and ſignificantly? Or is it God, who conſtantly and regularly performs the whole, according to certain primitive Laws, by which he has proportion'd and ſubmitted the Action of the Organs to our Deſires? Man knows neither the Organs or their Functions; and when by his reiterated Searches he comes to perceive the Effects thereof, or becomes able to diſtinguiſh them, at leaſt by their Names, it is always without underſtanding the Structure or Action of them. How then can he aſcribe to himſelf the Government of his Eyes? We are deſirous to ſee. This is all the Share we are allow'd to have in the Operation of our Eyes; and we are free from the Management and Care of all the reſt. Neither is it the Eye, which is endow'd with the neceſſary Intelligence, to level itſelf towards the Objects, in the manner, which is the quickeſt, and yet the propereſt to make it receive juſt and faithful Impreſſions thereof. It is then God alone who has ruled, and who fixes the Mobility of our Eyes upon our Wants; as it is he alone, who knows the Workmanſhip of the ſame. Thus he operates, as in the Eye, ſo in all the other Organs of Senſation, a thouſand and a thouſand different Motions, of which Man receives the Benefit, without ever being able to underſtand the Execution of them; and yet Man ſometimes asks, Where is God, and why keeps he at ſo great a Diſtance from him!

That Hand, which has ſo well mounted the Eye, and made it's Springs dependent on our very firſt Orders; nay, often on our very Wants, without waiting for our Commands, and eſpecially without perplexing our Reaſon therewith; that Hand, I ſay, makes itſelf ſtill more admired, in the Fitneſs and mutual Correſpondence of the Pieces, of which this Spying glaſs is inwardly compoſed. We have as yet ſeen only the Carriage and Supports of it.

In order to give you an Idea of what is done at the Bottom of the Eye, without making the Anatomy of it, which I am for the preſent to avoid; let us frame a rough Imitation of an Eye. Cloſe the Window-ſhutters of a Room, and fit a Tube of Paſt board of a Foot long, to a Hole that looks towards ſome publick Square. Let the ſaid Pipe be four or five Inches in Diameter, and cloſed next the Square with a Convex Glaſs of five or ſix Inches Focus, that is, which unites the Rays at the Diſtance of five or ſix Inches, and the Edges of which you muſt have cover'd with a ſmall Circle of Paſt-board, to hinder a too great Quantity of Light from entering. You are to introduce into this firſt Pipe a ſecond, cover'd with a fine Vellum, or a Piece of Ox-gut or of Bladder, tied on the End, which goes into the firſt Pipe. If in the Middle of the ſaid publick Place, into which your Window looks, there ſtands a Figure on Horſe-back or a Pyramid; let us chuſe out three Points of the Pyramid, one in the Middle, one at Top, and the third below, in order to judge from theſe three, of all the other Points, which likewiſe reflect the Light.

The Light from all Sides, or from all Parts of the Atmoſphere, falls upon theſe three Points. It is of courſe thence reflected every way. For you know that the Reflexion is equal to the Incidence; therefore a Bundle of Rays proceeds from the Middle of the Pyramid, and falls on the lenticular Glaſs faſten'd to the Window-ſhutter. What falls on the Diaphragm and beyond it, does not concerns us. Of all the Rays, which fall on all the Points of the Glaſs, that, which falls directly on the Middle, goes through the Glaſs and the Tube without any Inflexion. This then goes exactly to the Middle of the Vellum. Thoſe of the ſaid Bundle of Rays, which are ſomewhat oblique with regard to the latter, meeting a Surface of the Glaſs already inclined a ſmall matter, bend there and incline a little to the Perpendicular. By this Means, they draw nearer that of the Middle, and meet on the Vellum at the ſame Point. Thoſe, which fall farther towards the Edges of the Glaſs are more oblique, and are received on a more inclined Surface. There will they bend in proportion, and that Track, being more conſiderable, again brings them upon the Vellum at the ſelfſame Middle-point, on which the perpendicular Ray fell. All theſe Rays gather'd in a ſingle Point, ſtrongly paint in the Middle of the Vellum the Middle of the Pyramid. The Bundle of Rays, which from a Point arrives in widening on the Glaſs in the Form of a Sugar-loaf, may be call'd a Cone of Rays; and, on the contrary, the Bundle of Rays, which from the Glaſs where they have been bent, go and gather in a Point on the Vellum, we will call a Pencil of Rays; becauſe a ſingle one would produce on the Vellum too weak an Effect, whereas all theſe Rays gather'd from one Point of the Object on one Point of the Vellum, there very ſtrongly mark out one of the Points of the Image to be form'd thereon.

From the Point that terminates the Top of the Pyramid, imagine a like Cone of Rays falling on the Glaſs. The ſeveral Parts of that Cone bent in Proportion to their Obliquity will all meet together in a Pencil, the Extremity of which ſhall neceſſarily fall on the lowermoſt Part of the Vellum. Oe the contrary, there aſcends from the Foot of the Pyramid on the Glaſs, a Cone of Light, which ſhall go and gather into a Pencil-point towards the uppermoſt Part of tne Vellum; and the ſame will happen to all the Points of the Pyramid in proportion, and in moving the ſliding Pipe backwards and forwards, you will at laſt bring the Vellum to the focical Point, or to the exact Medium where the Union of the Bundles of Rays, proceeding from each individual Point of the Figure, and gathering into ſo many Pencils, ſhall be depicted in order. From all theſe Pencils, there reſult a Multitude of ſmall lively Points, all colour'd and exact, which being proportionably ranged among themſelves, as thoſe of the Pyramid are in large, preſent you with a perfect Picture of it on the Vellum, the Faithfulneſs of which far excels that of the Pieces of our greateſt Painters. But as the Rays, that come from below, gather at the Top of the Vellum, and thoſe, which proceed from the Right of the Obelisk, gather at the Left of the ſame Vellum, and ſo of the reſt, the Image is inverted; ſo that the Pedeſtal is above, and the Croſs below.

In thus ſhewing you what paſſes in that artificial Machine, I have, my dear Chevalier, reveal'd to you what paſſes in our Eyes. It is the ſame as to the Order and Operation. The Diaphragm of Paſt-board deſign'd to remove the Rays, which might come to diſorder the Image, by their exceſſive Multitude, and by the Inexactneſs of their Union, repreſents the Iris or colour'd Circle, which is on the fore-part of the Eye, with this Difference, that the Paſt-board always preſents the ſame Aperture to the Rays; whereas the Iris of the Eye, by the playing of it's minute Muſcles, in proper Time dilates the Aperture, which we call the Eye-ball, when we ſtand in need of a ſtronger Light; and ſoon contracts it, when an Exceſs of Light might either confound the Image, or fatigue the Organ. Do you paſs ſuceſſively from a dark Place into broad Day-light, and from thence into the Dark, with a Looking-glaſs in your Hand; you will ſee your Eye-ball widening in proportion as you enter into the Shade, and then contract in proportion as the Light ſhall be more or leſs glaring.

The Manner, in which the Rays are bent in the convex Glaſs, and in the Air, which follows it to the Vellum, is an Imitation of the Path of the Rays through the Humours of our Eyes; and as the Extremities of the Pencils form a clear and diſtinct, but at the ſame time an inverted Image on the Vellum, the ſame Pencils trace out on the Bottom of our Eye, a ſmall and very exact, but inverted Image of Objects. If after the Experiment of the Glaſs and Tubes, of which I have juſt ſhewn you the Uſe, you ſhould ſtill doubt of the Inverſion of the Image in your Eye, you might convince yourſelf of it, by placing at the Hole of a Window-ſhutter, which looks towards the publick Place, the Eye of a Sheep, or of an Ox freſh kill'd. After having curiouſly taken off the thick Envelopments, which ſurround the Bottom of the Eye, even to the tranſparent Pellicle, which incloſes the laſt Humour, it is fit you ſhould apply an oil'd Paper to it; then the Obelisk, which ſtands in the middle of the publick Place, the Houſes and Inhabitants, ſhall come and paint themſelves moſt clearly, and in a wonderful

Miniature, on the oil'd Paper; but all the Images will be inverted.

I ſhall be contented with this coarſe, but true Idea of the Functions of the Eye, which well deſerve, that one Day or other we ſhould make them a ſeparate Study. We now are able to judge of the other Wonders of the Uſe of the Eye and of the Light. But, to judge of them the better, let us chuſe ſome eminent Place, where our Eyes may perform their Functions without any Obſtacle, where we may be ſenſible how precious they are, from the very Beauty of the Proſpect it ſelf. We may place ourſelves either on the Flat of the Royal Obſervatory, or rather on one of the Towers of the Cathedral Church of *Paris*. So ſoon as I approach the Gallery, which is at the Top, one half of the Horizon of near or perhaps more than ſix ſquare Leagues, comes and paints itſelf in little on the Bottom of my Eyes, with ſuch Strokes as repreſent there the Mountains, the Royal Palaces with their Avenues, the Steeples of the Plain, and all the Buildings of an immenſe City. After having for a Moment indulged my Surprize at this raviſhing new Scene, a Croud of Reflexions offers to my Mind, upon all I am actually ſeeing.

The Multitude of Rays for one ſingle Eye.

My firſt Aſtoniſhment is, to perceive ſo much Order in that magnificent Picture, which covers the Bottom of my Eye, while an unutterable Confuſion reigns at the Entrance of the Eye-ball. From one ſingle Point of the firſt Object, I perceive, for Inſtance, the Top of the Steeple of *Sainte Chapelle*; there comes on my Eye a Bundle of Rays, which, in widening a little, covers the whole Aperture of the Eye ball. The Point of the Croſs immediately following, ſends thither another Pyramid, which fills a like Space, and all the Rays of which croſs every one of the foregoing. If there are a thouſand Points in the Croſs, which render it viſible to me by a thouſand the like Cones; there will be ten Millions of Cones, or radiating Pyramids, which will come from the whole Maſs of the Steeple, and every one of which ſhall (taken ſingle) make as many different Strokes on my Eye-ball, as there are Points contain'd in it. Theſe Lines croſſing each other over-power my

Reaſon, by a Croud, in which it loſes itſelf, and where it meets with nothing but Confuſion. What will then happen, when from all the Buildings of the Town, and from all the remote Objects of the Plain, the like Quantities of Rays ſhall come, and all meet at the ſame Entrance? The Iris, which ſecures the Entrance of the Eye, keeps off what is exceſſive, and admits only what is neceſſary; but that very Neceſſary is an Infinitude of Lines, united in the narrow Compaſs of the Eye-ball; and yet none of them ſhall go aſtray, but all follow their appointed Direction without any Miſtake. All ſhall orderly, and in ſmall Collections, go and lodge themſelves in different Quarters. All thoſe that come from the ſame Point, both from the Edges and from the whole Surface of the Eye-ball, again go and unite in a ſingle Point of the Retina, which covers the Bottom of the Eye; that being the Place of Reſort appointed for them. They are never confounded. They find their way in Spight of the Croud, and gather at ſuch Points as keep among themſelves, and in Miniature, the very ſame Order, which was obſerved among thoſe Points of the Object from whence they came.

2. Here is ſtill far greater Matter of Admiration. Theſe Objects before me are not deſign'd for me alone. I was ſurprized at the innumerable Quantity of the Rays they ſend forth, on a Space ſo little as is the Breadth of my Eye-ball. They then ſend out as many on all the like Spaces of the Maſs of Air, which encompaſſes them. For that Reaſon it is, that wherever I go, new Rays always replace the preceding, and not only the People, whom Curioſity has drawn to that Tower as well as me, but alſo Millions of Spectators, were they diſperſed on the neighbouring Towers and Eminences, might ſee the ſame Object as well as I. All the Rays, which would then ſerve them are really in Action, and want nothing but Eyes to work upon.

3. Among all theſe innumerable Rays, which from all Sides arrive at every Eye, thoſe, which preſent themſelves too obliquely, are reflected from, inſtead of being admitted into, the Organ. Theſe would enfeeble, or even confound, the Image of what is before us. But we ſhall make them of Uſe whenever we pleaſe, and we no

ſooner ſhall turn our Eye that way, but they will be admitted therein. They then come from all Sides, and their Miniſtry is always at hand. But an infallible Oeconomiſt has eſtabliſh'd Laws, which ſtop Part of them at the Door; that the reſt may be more uſeful and efficacious.

Efficacious, and inefficacious Rays.

4. All the efficacious Rays are not however the only ones admitted into the Eye. There are near theſe an infinite Number of others, whoſe Operations are more conceal'd, and which are drown'd by the Vigour of the firſt, but which are always ready to do the ſame Office in due Time. I, for Inſtance, make a Pinhole in a Sheet of Paper, and when I look through this Aperture, much narrower than that of my Eye, I ſtill perceive the Houſes of *Paris*; but the Proſpect of them is much more contracted, and Objects appear much ſmaller. The Rays, which form'd the firſt Image, ſhew'd it me larger only by Refractions, the Meaſure of which depended on their greater Obliquity. Thoſe, which form this new and ſmaller Image, then ſuffer ſmaller Refractions; they conſequently have leſs Obliquity, and are indeed other Rays. Therefore, wherever we carry our Steps and Sight, we find a new Light, and deſcry the Preſence of an infinite Wiſdom, which for our ſake ſets innumerable Springs a-going, and is willing that this Light ſhould be a beneficial Guide to us; even at a Time when it is diſpenſed to us in the ſmalleſt Quantity.

5. And indeed that Portion of Light, which from the Sun deſcends upon the Earth, is from the Surface of our Abode reflected to the upper Parts of the Atmoſphere. Theſe upper Parts, or that Maſs of Air and rarified Waters, is clear enough to admit the immediate Impreſſion of the celeſtial Light, and at the ſame time preſents a ſufficient Number of ſmall Surfaces to the Light reflected from the Earth, to bend it towards the Earth again. It falls and falls again on Objects; daſhes from one another, and is divided every way from each individual Point. Thus a ſingle Point firſt reflects a ſtronger Light; then one leſs ſtrong; then a middling Light, and then a Light ſomething weaker. All the Returns of theſe reflected Rays are as much varied as are the Incidences. The Eyes,

by this Means, receive from all Sides, and from the ſame Objects, Rays of ſeveral Degrees of Strength, and of various Obliquity, which produces a Variety no leſs infinite in the Effects.

6. But if we compare that Light, which enlightens our terreſtrial Globe, with that, which fills the whole Sphere of the Sun, and of the Planets known to us; what we juſt now admired with Amazement, dwindles even to nothing. Af all the vaſt Abyſs of Light, which the Sun preſſes on all Sides, and which he makes to radiate, even to the very Stars, we only ſhare that faint Light, which is reflected from the Planets towards us, together with the more abundant Portion of it, which falls immediately on the Earth. But if the Earth be no more than a Point in that Sphere, what can be the Light, which falls thereon? What can be that Portion of Light, which enlivens all its Inhabitants, which unveils ſo many Objects to them, which has ſo much Force, Activity, Suppleneſs, and Variety in its Effects, which, in ſhort, is unfathomable to our Underſtandings, for the Multiplicity of theſe its Operations? To ſpeak the Truth ſincerely; if the Earth be but a Point, all our terreſtrial Light is but a ſingle Line deduced from the univerſal Light.

7. This is, indeed, the Place to make great Calculations, and find out vaſt amazing Sums, by multiplying the Cones of Light by the Points of the Objects; then again, by multiplying theſe Products by as many Breadths of an Eye-ball as the Atmoſphere can contain; and finally, in multiplying this laſt Product, by as many like Atmoſpheres, as there may be contain'd in the Space of the hundred millions and more of cubic Leagues enlighten'd by the Sun. But inſtead of giving you whole Pages of Figures; let us reſt ſatisfied with the Calculations of one of the greateſt Admirers of the Works of God. * *How precious are thy Wonders unto me, and how great is the Sum of them! If I would count them, they are more in Number than the Sand of the Sea ſhore. How much ſoever I conſider them; how earneſtly ſoever I endeavour to gain the End, or comprehend the Greatneſs of thy Works and thy Perfections; ſtill*

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* Pſal. cxxxix. 17, 18. and following, according to the Hebrew.

ſtill am I with thee. Whatever I ſee, like thee, is inexhauſtible; and after all my Calculations, I am juſt where I was.

Though it be a Benefit to us now and then to preſume to get a Glimpſe of the Infinite, becauſe we are never more ſenſible how far this adorable Being carries his Kindneſs towards us, than when we are moſt convinced of our extreme Littleneſs; yet is is of very ſmall Uſe to conſume our Time in Calculations, which diſtract our Heads, and in Arguments on Infinitude, which will always be very much below the Thoughts of the Creator. It is undoubtedly much better, generally to employ our Thoughts upon what he places within our Reach, and on what, in his Works, is moſt proper to affect our Minds. It is then enough for us, at a Diſtance, and as through a Veil, to have view'd the Sources of the Light; to have traced it through its Paths, and to know the all-wiſe Laws, which inſure to every Eye that Portion of Light, which is neceſſary to them. Now, let us behold the Wonders of that Picture, which the Rays delineate at the Bottom of the Eye; ſince it is that Picture, which becomes our proper Light, our Guide, and our Flambeau.

8. What ſurprizes me firſt herein, is a perfect Diſtinction and Clearneſs, together with the utmoſt Littleneſs. We ſometimes are amazed, on ſeeing a Pourtrait, very like, encloſed within the Bezil of a Ring. But here is one half of the Horizon of *Paris*, that is, a Space of above ſix ſquare Leagues, faithfully repreſented within the Compaſs of not quite half an Inch. Here the Calculation is very eaſy; ſix Leagues, at the Rate of two thouſand Fathoms for each League, as they reckon them at *Paris*, make twelve thouſand Fathom; which being multiplied by themſelves, to make the Area of that Surface, will amount to one hundred and forty-four millions of Fathoms. I would fain know, what Space or Room the Picture of one of the greateſt Objects I ſee on the Plain, can fill in my Eye, or nearly ſo. But as the Objects, which are very near me, fill a very great Space in my Eye, becauſe they are more conſiderable with Regard to me; and the moſt remote take up therein but a very narrow Room, becauſe they muſt affect me leſs; let us chuſe an Object but at a

middle-diſtance, that we may obtain a more exact Degree of Proportion. The largeſt Builing, which offers at a middle diſtance in this vaſt Proſpect, is the Gallery of the *Louvre*. It is not quite one hundred and fifty Fathoms long. Let us join it to the Pavillion of the *Tuilleries* on one Hand, and to the *Old Louvre* on the other, which, together, let us ſuppoſe make two hundred Fathoms. The Heighth quite to the Top is hardly more than forty-eight Foot or ſix Fathoms. The vertical Section, or the Surface of it, will then be two hundred Fathom by eight; that is, one thouſand ſix hundred ſquare Fathom; which makes the ninety thouſandth Part of one hundred and forty-four Millions. Now there is the ſame Proportion between the Space which the Image of the Gallery of the *Louvre* fills in my Eye, and the Image of the whole Plain, as between the Gallery itſelf and the Plain. Conſequently, this magnificent Gallery, with its fifty large Windows, and thoſe of the *Louvre*, which I perceive diſtinctly, fill in my Eye no more than the ninety thouſandth Part of half an Inch. How wonderful a Picture is this! But what a Maſter-painter too!

9. I perceive on the Plain a Coach, which inſenſibly goes from the Village it left, and by little and little gets into the Avenues of *Paris*. If I have a mind to meaſure in the ocular Picture of the Plain the Space, which correſponds to the Dimenſions of one League, which I ſaw the Coach make; a League of above two thouſand Fathem ſhall not, by much, take up at the Bottom of my Eye the Space of one ſingle Line. What Space does then the Coach and Horſes fill up in the Eye? And if I cannot judge of their Motion, but by the ſucceſſive Alterations of Place made within my Eyes, of the ſmall Image, which repreſents their Feet; this Image muſt not only have moved on five or ſix thouſand different Points; but alſo have fetch'd five or ſix thouſand proportional Paces within the Length of that Line. The little Horſes, which the Light has painted at the Bottom of my Eye, continually change their Place there, and after a Courſe of half or three quarters of an Hour, they at laſt have finiſh'd the croſſing over a twelfth Part of an Inch.

10. This wonderful Picture, thus form'd at the Bottom of the Eye, is the Effect of the three Humours, which

divide it. If the Bundles of Rays, which come and ſucceſſively bend therein, ſhould be gather'd into Pencils there, before they ſhould touch the Bottom of the Eye; or ſhould they touch it before all their Strokes were gather'd into a Point; the Organ would indeed be ſhaken; we ſhou'd have the Perception of the Preſence of the Light; but the Image being not form'd by an Order of Points, which ſhould imitate the Order of thoſe of the Object, from which the Bundles of Rays came, the Viſion would be confuſed.

The radiating Crowns of luminous Bodies.

Let us not here overlook the Uſe, which God makes of thoſe very Rays, which moſt ſtrike upon our Organ, and arrive thither in the greateſt Diſorder. Nothing makes a greater Impreſſion on the Eye, than thoſe long Strokes ſo uneven and ſo bright, or the Irradiations, which attend the Image of luminous Bodies. Whence can thoſe Strokes proceed? How do they act? What are they deſign'd for? God has placed at the Extremity of both the Eye-lids a Border perfectly round, always moiſten'd with an Oil, which iſſues from it through ſmall Orifices, and makes it at all times of the cleareſt Smoothneſs and Gloſs. By that Means the Eye-lid ſlides over the Eye, without any Roughneſs, and from time to time bruſhes it, to clean it of the very minuteſt Dirt or Duſt, which the Hair of the Eye-brows or of the Eye-lids had not been able to ſtop perhaps or keep off. But that Border or String has ſtill another very different Effect. It is a true Looking-glaſs, rounded and prepared to reflect on all Sides, by that Roundneſs, the Light that falls thereon. The Light, which luminous Bodies ſend thither, is always more active, and that Part of it, which ſhall enter the Eye-ball, will always make a powerful Impreſſion there. But there is but a very ſmall Number of Rays reflected from the Border of the upper Eye lid, toward the lower Part of the Eye-ball, that can enter it, as there is but a very little Quantity of Rays, reflected from the Border of the under Eye-lid towards the higher Part of the Eye-ball, that can be admitted therein. Theſe Strokes, which, as you ſee, enter the Eye but obliquely, can never regularly paſs through all the three Humours, nor bend in order to gather there, and conſequently form neither Pencils or any Images; but they ſtrongly ſtrike on the Organ by the Image, which is at the Bottom of the Eye; and as theſe Strokes proceed from a Light, which paſſes between the Hairs of the Eye-lids, they neceſſarily are confuſed and broken into long Streakes, the Breadth of which reſembles the uneven Separations of the Hairs. Thence proceed the radiating Crowns, which encompaſs the Image of a Candle ſeen at a great Diſtance, and, above all, the Image of the Stars and the Sun. Would you be certain of the Fact? Draw your Eye-lids very near one another, at the Sight of a luminous Body; in uniting a very great Number of Hairs, to break the Light, which arives on the round Borders, you increaſe the Number of the large Strokes, ſo far as to confound and perplex the Image of the luminous Body. Have you a Mind to produce a quite contrary Effect in your Eye? Take a Wheat-ſtraw, the ſmalleſt Part of it eſpecially, and neareſt to the Ear; put the End of it through a Paper, and look at the Sun through the ſmall Hole of that Pipe; the Rays, which come through this narrow Channel, do not by much fill the whole Compaſs of your Eye-ball; and this ſhall render the Image of the Sun, or of any other Object, much ſmaller. But if the Rays of the Sun cannot this Way get at the Borders of the Iris, which regulates the Opening of the Eye-ball, much leſs ſhall they reach the Borders of the Eye-lids, which are ſtill more remote; but then, you will ſee radiating Crowns no more. Perhaps ſome few Rays, reflected from the Inſide of the Straw, ſhall at moſt ſhew a few feeble Strokes here and there, and ſeveral varying Colours round the ſolar Image; but the large Strokes will be entirely vaniſh'd, and a Star ſeen through a Pin-hole, or a long Pipe, is no more than a ſingle Point without any Splendor or Beauty.

Let ungrateful and extravagant Minds (for I ſhall make no Diſtinction between them) ſay after this, that he, who made the Stars, had then not Man in View. It is ſo very true, that he made the Stars for the Eye, and the Eye for the Stars; that, in order to inſure the Services of theſe remote Globes to Man, and to render the Impreſſion of them lively and affecting to him, notwithſtanding their extreme Remoteneſs; he took the Caution to diſpoſe round the Eye. two cylindrical Looking-glaſſes. which, without forming any Image, embelliſh, ſtrengthen, and ſet off, by a radiant Circle, the Image of the Star, or of the inflamed Body delineated in the Eye. You had hitherto look'd upon the two Pads, which ſurround our Eye-lids, as two very indifferent or inſignificant Things; but the weakeſt Inſtruments become fruitful in great Effects in the Almighty's Hands. The Sun, with all its Fires, would not afford us the Splendor of the Day, were it not for the Bubbles and Spherulæ of the Atmoſphere. The Light, reflected from the whole Cieling of the Atmoſphere, would not render Objects viſible to us, were it not for the Humours of our Eyes; and it is from the bare encircling of two ſmall round and glazed Strings, that God, for our ſake, borrows the chief Brightneſs of domeſtick Lights, the fineſt Strokes wherewith he crowns the Sun, and the whole Glory of the Heavens in general.

11. But we ſhould ſtill remain in Darkneſs, and in a real Chaos, notwithſtanding the all-wiſe Proportions God has put between the Structure of the Light and that of our Eyes, in order to make us correſpond in general with the Univerſe; did he not every Moment create in us a particular kind of Senſations, whereby his Deſign is to inform us regularly of the Preſence of what is round us. The Light, the Eye, and our Senſations, do then proceed from the ſame bountiful Hand, and from the ſame benign Intention. If Animals have a Share in the ſame Advantages, as I believe I have demonſtrated to you, that they were provided with Senſes capable of guiding them, purpoſely that they might free us of a great many Cares, and in a Word, that it is for us alone they live and ſee; the Succours, which enable our Domeſticks to ſerve us well, ought to raiſe our Gratitude rather than our Jealouſy. The great and important Truth which preſents itſelf here, as a Reſult of ſo long a Series of Wonders, is, that we inceſſantly experience in the Heavens, on the Earth, and within ourſelves, the Action and Influence of an infinite Wiſdom, which ſeems to have made it her Buſineſs to govern us, and her greateſt Delight to dwell amongſt us.

The Light reflected from a Tree, and bent within my Eyes, may affect them, 'tis true; but it delineates two Images in my Eyes, and I ſee but one Tree. It paints in my Eyes an inverted Image, and I ſee the Tree in a direct Situation and upright. It paints in my Eye a Tree, which does not by much fill the hundred thouſandth Part of one Line, and the Tree I ſee is eighty Foot high. I myſelf am not ſix Foot high and two Foot broad, and have the moſt real Senſation, not only of a very large Tree, but of the Plain of *St. Denis*, and of the Diſtance which is between the Earth and the Sun. Sure this is incomprehenſible. But it is but the more evident, that this Marvel is the Work, not indeed of the Light, which can only agitate the Bottom of my Eye, nor of Nature, which is an Idol, a mere ideal Power void of Reality; but of God alone, who intimately operates within me. Therefore, the Sight of a Tree and of the Sun, which God ſhews me, is as real and as immediate a Revelation as that, which led *Moſes* towards the burning Buſh. The only Difference between both theſe Actions of God on *Moſes* and me, is, that the firſt is out of the common Order and Oeconomy; whereas the other is occaſion'd by the Sequel and Connexion of the Motions God has eſtabliſh'd to rule both Man and Nature.

12. The Habit of ſeeing ſo ſoon as we open our Eyelids, make us look upon that Operation as a Thing extremely plain and intelligible. However, I ſhall boldly aſſert, that the Myſteries of our holy Religion are not more above our Underſtandings, than the Manner, in which we ſee, or than that inmoſt Sentiment, which we experience, of the Diſpoſition and Magnitude of the Things, which are ſo remote from us. That my Eye, by the Help of an Image but ſix Lines broad, or my Soul with an Organ of half an Inch, ſhould ſee eight or ten ſquare Leagues, and diſcern the Beauty, the Form, the Situation, and Diſtances of one million of Objects diſperſed all over this Plain, is a Myſtery truly inacceſſible to all our Reaſonings. That Operation muſt either be corporeal or ſpiritual. But whatever it may be ſuppoſed to be, it will in both Caſes be equally above our Reaſon. It is an unfathomable Abyſs; but it is a Truth, and an undoubted Matter of Fact. What I can conceive of it,

(and that is a great deal for me) is, Firſt, That God being alone able to work this Marvel within me, I continually experience the Effects of his Preſence and Goodneſs: Secondly, That in Nature, as well as in Religion, he is pleaſed to grant me the Uſe and Communication of certain Bleſſings, and of certain Truths, without unveiling to me as yet the Ground and Nature of what he vouchſafes to inform me of; and, in ſhort, that to diſpute proved and well atteſted Truths, by alledging, that one does not conceive them, is as little reaſonable, as if I ſhould ſay, I actually do not ſee *Paris*, nor its Churches, becauſe I don't conceive how, being ſo little, I could have the Perception of ſo vaſt an Extent. Unbelievers build on the Authority of this Principle of modern Philoſophy, *viz.* not to admit of any Thing, but what we clearly and evidently know. Let them ſay then, when they open their Eyes to the Light; *I ſee nothing*; *for I conceive not how any one can ſee.*

THE
COLOURS.

DIALOGUE IX.

INSTEAD of a Field embelliſh'd with all the greateſt Beauties, which the Spring and the Art of Man may convey and gather there; let us conceive this all over-cover'd with Snow. The Light of the Sun, which begins to aſcend our Horizon, is ſtrongly reflected by that univerſal Whiteneſs, which overſpreads it. The Day is conſiderably brighten'd thereby. Our Eyes may freely expatiate over the whole Plain, its Surface being perfectly open'd before us. Every thing is enlighten'd and viſible, and yet confuſed and undiſtinguiſh'd there; and this Confuſion of the Objects does not properly proceed from the Thickneſs of the Snow, which covers them; for the River is ſtill ſenſibly lower than the Meadow; and the Meadow lower than the arable Grounds. A Tree and a Houſe have always a proper Form, which helps us to diſtinguiſh them tolerably well; but we muſt be at the Trouble to gueſs; and the Uniformity of the Whiteneſs, notwithſtanding its Splendor, hinders us from diſtingiſhing the Rocks from the Habitations of Men, the Trees from the Hills, which bear them, the till'd from the untill'd Lands.

The Diſtinction of the Objects.

We then ſee all, but can diſtinguiſh nothing. Such would have been the Aſpect of Nature, had God allow'd us Light without the Diſtinction of Co-Colours.

We every Day admire that noble Art, which, by lightly ſpreading a few Colours on a Cloth, makes us ſee thereon Objects, which do not exiſt. It deceives us by ſhewing us a mere Outſide and Drapery. But if this Diſtinction of Colours skilfully managed is alone ſufficient to make Realities appear to our Eyes, where there are none; it very plainly ſhews the bountiful Intention of him, who has painted and cloath'd whatever is round us. Each individual Piece was by him render'd diſtinguiſhable. Each Kind wears it's peculiar Livery. Whatever is for our Uſe has a diſtinguiſhing Mark, which characterizes it. We need be at no Trouble, when we want to diſcover the Things we look for. The Colours point them to us.

To what Delays and Perplexity ſhould we have been reduced, had we been obliged every Minute to diſtinguiſh one Thing from another by Reaſonings? Our whole Life muſt then have been employ'd rather in Study than in Action, and we muſt have remain'd in that eternal Uncertainty, in which Naturaliſts ſometimes are with the moſt magnificent Hypotheſes, or as Chymiſts, after a thouſand and a thouſand Diſſolutions or Decompoſitions.

God's Intention was not to buſy Mankind about empty Speculations; and it is plain, that he conceal'd from us the Ground and Principles of Beings, in order to recal us effectually to the Neceſſaries of Life, and the Practice of Virtue. The Earth was not made to lodge Philoſophers apart, and ſolitary Dreamers, but to be cover'd with a Society of Brethren, bound to each other by Wants and reciprocal Duties. For this Purpoſe it was, that God, inſtead of the long and tireſome Method of Inquiries and Reſearches into the Nature of Individuals, was pleaſed to grant Mankind, and even the Animals that attend them, the commodious, eaſy, and expeditious Way of diſtinguiſhing Objects by their Colour. Man opens his Eyes in the Morning, and, behold, all his Reſearches are made. His Work, his Tools, his Food, and whatever concerns him, clearly offers itſelf to him. He is at no manner of Loſs to diſtinguiſh Things. The Colour is the Ticket that guides his Hand, and infallibly leads it whither it ought to go.

The Ornaments of Nature,

The Deſign of making us quickly diſtinguiſh Objects at Sight, is not the only Thing that gave Birth to Colours. In this, as well as in every thing elſe, God has had reſpect to both our Pleaſures and our Wants. To what other Purpoſe than that of placing us in a delightful Abode, can he have adorn'd all the Parts of it with Pictures ſo ſtriking and ſo diverſified? The Heaven, and whatever is ſeen at a Diſtance, were drawn at full Length. Splendor, Sublimity, and Loftineſs of Style, are the Character of them; Lightneſs, Delicacy, and all the Beauties of Miniature, are found again in Objects deſign'd to be ſeen nearer, ſuch as Leaves, Birds, and Flowers; and leſt the Uniformity of Colours ſhould become in a manner tedious, the Earth changes it's Garment and Attire at every Seaſon. The Winter, indeed, robs it of a great Part of it's Beauties; but it brings on again a Reſt, which is of Uſe to the Earth, and ſtill of greater Uſe to him, who cultivates it. Why ſhould the Earth, while Winter detains Man within his Shelter, adorn herſelf with Attire, not to be ſeen by her Maſter?

and of Mankind.

Theſe Colours, which make ſo beautiful an Effect in Nature, are no leſs an Ornament to Society and Mankind. They facilitate all their Operations, as they do thoſe of a great Army. They every where aſſiſt Subordination, by diſtinguiſhing Conditions. What a Comelineſs do they not communicate to our Cloaths and Furniture? They for ever give Employment to the Pencil, the Graver, the Shuttle, and the Needle; but after theſe have had their firſt Preparation under the Hand of the Artiſt, they ſtill are improved, in being placed with Decency, and match'd with Judgment and Taſte. This laſt Merit they generally acquire from the Induſtry of Ladies.

But of all the Services Colours do to us, the moſt engaging is, their ſo well anſwering all our Intentions, and ſo readily agreeing with all the Situations of our Minds. The moſt common Colours ſerve for ordinary Uſes, and for Things of little Concern. The moſt lively and brilliant are reſerved for more notable Occaſions. They enliven our Feaſts, and by their Splendor convey every where a ſecret Joy and Satisfaction, almoſt inſeparable from them. Are we in Affliction? Other Colours then take Place. They ſurround us with Mourning, and it is a ſort of Comfort to us, to ſee whatever approaches us concern'd for our Troubles, and ſharing our Affliction with us.

Theſe Colours deſign'd to vary ſo uſefully the Scene of the World, greatly deſerved to be follow'd a Moment, in the Enumeration of the Uſes, for which they are fit; and we thereby conceive, that they have a Rank among the fineſt Favours of the Creator. But could we know what they are in themſelves? Are they inherent in the Objects? Do they exiſt in the Light? Do they reſide only within us?

The Nature of Colours.

It is with Colours as with all our other Senſations; they are partly within, and partly without us. What affects our Soul immediately, is properly no where but within ourſelves; but what we experience is relative to what paſſes within us. I feel a violent Pain when the Fire burns, or a Needle pierces my Hand; but the Smart I feel is neither in the Fire, or in the Needle. Flowers may indeed exhale ſome Spirits; but the Smelling is no where but in me. Muſical Inſtruments, when ſtruck, do really ſhake the Air; but the Sound and Harmony affect the Soul alone.

Thus the Red, which exhilarates me, and the Black, which makes me ſad, are ſo many Perceptions of the Soul, and ſo are all other Colours. They are ſo many lively Notifications that we receive of what paſſes about us. Theſe Sentiments are ſo truly our Property, they are ſo really within, not without us, that by the Effect of an Order eſtabliſh'd to keep our Souls always buſy, we in our Sleep ſtill experience the ſame Senſations, the ſame Smells, the ſame Savours and Colours, though there are no longer any external Objects to excite them. In vain would one ſay, that theſe are only the Remains of the Senſations we have experienced, revived again with us; nothing but a remaining Emotion, which blends itſelf with ſeveral others within the Brain, and is follow'd by the Senſation annex'd thereto. I grant it. But the Reality of that Senſation is the ſame as when we are awake. We then ſee the ſame Colours, the ſame Objects, and at the ſame Diſtances. None but an infinitely powerful Being, none but a Being intimately preſent every where, can thus cauſe and perpetually create in us all theſe ſo exquiſitely regular Senſations, which put us in a Correſpondence with every Thing about us. And as thoſe Motions, which diſplace and tranſport Bodies, are the Order, after which God acts upon Bodies; ſo that the ſeveral Degrees of theſe Motions are ſtill no other than the Actions of God diverſified; ſo likewiſe the Senſations, which affect our Souls, are the Order, after which God acts upon our Soul; and all the Varieties of Savours, Smells, Sounds, Colours, in ſhort, all our Senſations, are nothing but God's acting on us, diverſified according to our Wants.

Let us not glance upon this Truth too ſlightly. Every Thing contributes to convince us of it. The Bodies, which ſurround us, do not come and graft themſelves upon our Mind; nor does our Soul get out to diffuſe itſelf outwardly, and to become acquainted with what paſſes there. The Light, which extends from the Objects to us, is nothing but a Maſs of Corpuſcles, which can at moſt only ſtrike my Eyes variouſly; and this or that Impreſſion is not of itſelf more fit to cauſe the Senſation of Yellow, than that of Purple. I perceive therein an Oeconomy entirely free, and that theſe Perceptions, ſo exquiſitely regular, are the Work of an Almighty Being, who has eſtabliſh'd and makes us ſenſible of them in an uniform Manner, to acquaint us of whatever may be to us of Concern. How affecting this Truth is! And how fit too, to maintain within me an awful Senſe of the Preſence of Him, who communicates himſelf to me by intimate Influences, by Advices, and by perpetual Favours! But this Revelation, which God makes perpetually to us of the whole Oeconomy of Nature by the Miniſtry of our Senſes,

The Ways of the Light.

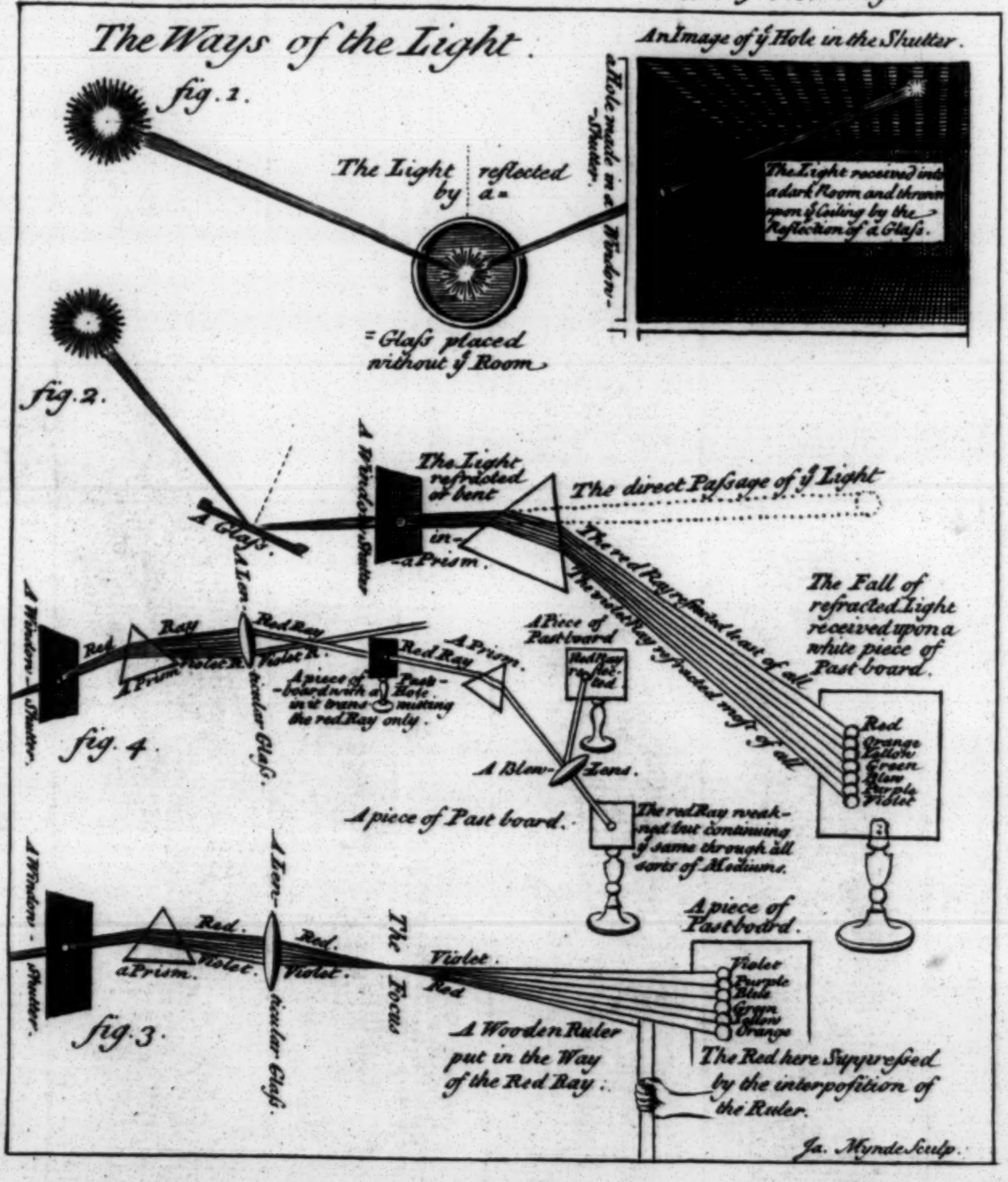
fig. 1.
An Image of ye Hole in the Shutter.
a Hole made in a Window-Shutter.
The Light reflected by a=
=Glass placed without ye Room
The Light received into a dark Room and thrown upon ye Ceiling by the Reflection of a Glass.
fig. 2.
A Glass.
A Window-Shutter
The Light refracted or bent in-a Prism.
The direct Passage of ye Light
The red Ray refracted least of all
The violet Ray refracted most of all
The Fall of refracted Light received upon a white piece of Past-board.
Red
Orange
Yellow
Green
Blew
Purple
Violet
fig. 4.
A Window-Shutter.
Red
Ray
A Prism
Violet R.
A Lenticular Glass.
Red Ray
Violet R.
A piece of Past-board with a Hole in it transmitting the red Ray only.
Red Ray
A Prism.
A Piece of Pastboard
Red Ray reflected
A Blew-Lens.
A piece of Past board.
The red Ray weakned but continuing ye same through all sorts of Mediums.
fig. 3.
A Window-Shutter.
Red.
a Prism.
Violet.
A Lenticular Glass.
Red.
Violet.
The Focus
Violet.
Red
A piece of Pastboard.
Violet
Purple
Blue
Green
Yellow
Orange
A Wooden Ruler put in the Way of the Red Ray.
The Red here Suppressed by the interposition of the Ruler.
Ja. Mynde Sculp.

is become ſo familiar to us, that we ſcarce know the Author of it again; and we complain of either his Unconcern or his Remoteneſs, while we both receive from, and have in him our Senſations, Motions, and Being *.

But if the Colours, which touch us immediately, are nothing but the Action of God, diverſified in us by the Preſence of the Bodies round us, we may now inquire, what are in Nature the Accidents, Strokes, and Motions, to which God has annex'd the Senſations, by which he affects our Souls. If what, by ſtriking on our Eyes, gives Occaſion to the Senſation of the Red Colour, is conſtant, and ſomething different from what produces in us the Impreſſion of Green; what ſhould hinder us to call that a red Ray, or a red Body, which is the occaſion of our ſeeing that Colour, or to call that a yellow Ray, or a yellow Body, which excites in us the Senſation of Yellow; ſince all Ambiguity was removed, by rightly diſtinguiſhing the Perception of ſenſible Colours, which is only within us, from the Strokes, which proceed from external Objects, and which are properly corporeal Colours?

The Colours of Light.

Theſe are of two Kinds. Some are in the Rays of the Light themſelves; others are in colour'd Bodies. That there are in the Light Rays eſſentially red, others of another Colour peculiar to them, or, in ſhort, Rays differently framed, is what can no longer be doubted, after the Multitude of Experiments, which Sir *Iſaac Newton* † made with all imaginable Succeſs, for his own Information on that Point; let us ſatisfy ourſelves with the plaineſt and moſt practicable of them. They make in a Window-ſhutter a ſmall Aperture of an Inch in Diameter. When the Sun ſhines bright thereon, the Rays received through the Hole into a Room made dark, go and paint the Image of the Sun, or of the round Aperture on the Wall, or on a Cloth, or on a Screen ſet to receive them. If, cloſe to the Aperture, you preſent to the Rays of the Sun the Side of a Priſm, that is, of a triangular Glaſs

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* In him we live, and move, and have our Being, Acts xvii. 28.

† Conſult Newton's Optics, Graveſand's Inſtitutes, and the Experiments, which are made at the Abbe Nollet's, Quai Conti.

well choſen, ground true and ſmooth; the Figure, which the Rays then make upon the Cloth, is no longer round as before. It ſtill remains of the ſame Breadth; but it becomes very long, is terminated by two ſtrait Lines in it's Length, and rounded at only either End. Towards one of the Extremities of this Figure, you perceive the fineſt Red, then the Orange-colour, then the Yellow, and next the Green, the Blue, the Purple, and the Violet. Theſe ſeven Colours do not ſtart and glare upon one another; but you ſee between every two of them gentle Gradations, which partake of the neighbouring Colours, and have ſomething of a Mixture or Confuſion in them. After having attentively examined this extraordinary Figure, they found out that it was compoſed of Rays differently colour'd, and which being in themſelves of a different Nature, go through quite different Tracks in the Glaſs, and therefore are differently refracted or diverted, ſo as to fall on the Cloth, at Points variouſly diſtant from that whereon they all ſhould have fallen, had they not been refracted in the Glaſs. A flat Glaſs is not fit to produce this Effect; becauſe the Thickneſs of it being equal every where, and the ſame; the different Rays, which ſuffer different Refractions there, are in proportion very differently bent in their coming out of the Glaſs into the Air, which brings them again to their firſt Progreſſion; ſo that they ſeem not to have been bent. They remain ſo near each other, and ſo much blended, that one Colour does not overpower the other. But if the different Rays have the leaſt Inclination in their own Nature, to be bent or refracted differently from each other in the Glaſs; this Difference ſhall become ſenſible, if they fall obliquely on a Glaſs, whoſe Thickneſs continually is increaſing. For two Rays, which in going into a flat Glaſs incline towards the Perpendicular, with a very ſlight Difference or Inequality, will come out of it quite cloſe to each other, and without forming any ſenſible Angle. But if, in their entring the triangular Glaſs, they be bent with a Difference ever ſo little; that Ray, which falls a little lower in the Glaſs, having a greater Thickneſs to go through, increaſes it's Divergency. When afterwards both theſe Rays ſhall come into the Air, their Separation, ſtill inconſiderable, though very real, will become more ſenſible. At the Diſtance of ſome Feet more, the Sides of that Angle will have a ſtill greater Divergency; and at twelve or fifteen Foot Diſtance, two Rays, which in the Glaſs were divided but a ſingle Point, will be ſeparated by an Interval of half an Inch. The Ray, which is the leaſt diverted from it's firſt Direction, or leaſt refracted, is the Red. That, which receeds moſt therefrom, is the Violet; but then the Red is always at one End of the Spectrum or Figure. The Purple is at the other End. The reſt of the Colours are between them in the aboveſaid Order. The red Ray is not ſingle, any more than the Yellow or the others. But after a deeper Red, there comes a Red of another Degree. The ſame Tones, Diminutions, and Gradations, are found in the other ſubſequent Colours. Every one of theſe Rays throws on the Cloth a round Figure, correſponding to the Aperture of the Window-ſhutter. And as theſe ſeveral round Figures are but little diſtant from each other, thence proceeds the Medley of the neighbouring Colours in that Liſt of Figures that touch each other. Hence the Uniformity of the Breadth of the whole Figure. Hence the two ſtrait Lines, which terminate it, and which are nothing but the Extremities of all thoſe round Figures delineated by all the different Rays. Hence, in ſhort, the Roundneſs of the two Ends of the Figure, where the two Extremities of the two round Images delineated by the Red and the Purple, muſt neceſſarily be. All theſe Circles, delineated by ſo many differently colour'd Rays, and from which a longiſh Figure rounded at both Ends reſults, can never be better repreſented than by a Row of Gold, Silver, Copper, Braſs, and other metal Coins ranged on a Table, and covering each other more than one Half. This Row of Counters is of ſeveral different Colours, bounded all along by two Lines apparently ſtrait, and at laſt rounded at both Extremities.

If theſe ſeveral Rays, after having paſs'd through one firſt Priſm, are received into a ſecond, and then into a third, there they ſuffer greater Refractions, and form an Image ſtill longer, but never loſe their Nature, and conſtantly keep the ſame Order among themſelves. The Red is always firſt. Then follows the Orange-colour.

What was yellow in the firſt, ſtill remains yellow in the third Priſm. The Green never loſes the middle place; in a Word, each Ray keeps it's Colour invariably. To be the more certain of this; preſent a Wire, or a Slip of Paſt-board, to the Point of the firſt Priſm, where the Beginning of the Light paſſes; if you do it on the Side where the red Ray is, that Colour diſappears on the Cloth. Bring the Wire a little further, the red Ray immediately ſhews itſelf again, and the Orange-colour vaniſhes. You thus make them ſucceſſively vaniſh and return in the Figure or Spectrum at your Pleaſure. It is not then the Mediums, through which the Rays paſs, that gives them different Colours; but the Mediums, and all Bodies in general, receive theſe Colours from the Rays themſelves, every one of which is of a peculiar and invariable Nature. You may even make yourſelf ſtill ſurer of it. Stop the Maſs of Rays, which croſs your Chamber, by putting a Piece of black Paſt-board with a ſmall Hole in it in the Way. Through this Hole receive only the red Ray, which you ſeparated from the reſt by means of the Priſm; it ſhall go and mark out a ſmall red Spot on the oppoſite Cloth. Make this ſingle Ray paſs through a ſecond, a third, and a fourth Priſm, or through a yellow or a blue Glaſs, yet will you have no other but a red Spot. Likewiſe, if you receive a blue Ray, it will remain blue in all the Mediums, into which you ſhall introduce it, and in all the Proofs, which you ſhall be pleaſed to make of it.

The Rays have then in the corporeal Light, Firſt, A Colour and a Conſtitution peculiar to every one of them. Secondly, They have each it's different Degree of Refrangibility, that is, of Diſpoſition to be refracted or bent. They have a third Property, *viz.* That the moſt eaſy to be bent in the Glaſs, is likewiſe the eaſieſt and ſooneſt reflected, when it reaches the Surface of the Air on the other Side of the Glaſs. Thoſe, which have the greateſt Refractions, are the firſt reflected, when the Obliquity of the Air, into which they tend through the Priſm, becomes great. For this Reaſon, when they give the Priſm a Motion, which increaſes the Obliquity of the Light, with regard to the laſt Surface of the Glaſs, and conſequently with regard to the Air, which touches that Surface; the

Purple is the firſt Colour, to which the Air on the other ſide the Priſm refuſes a Paſſage, and which being totally reflected in the Priſm, diſappears in the long Figure projected on the oppoſite Cloth. If, by inclining the Priſm, you a ſmall matter increaſe the Obliquity of the Rays, then the Indigo-Colour vaniſhes, then the Blue, and ſo of the reſt. The Red however is the laſt that leaves the Place.

But when thoſe Rays, which we but now ſaw ſeparately, by means of the Priſm, are united and concur; then it is that they produce a Marvel far more ſurprizing than all we juſt obſerved. According to our Notions, they ſhould be much alter'd by their Re-union, and make a dull muddy Colour; as happens to the Colours of Painters, when they are blended together on the Pallet. The Reverſe of this happens to the united and concurring Rays of the Light. They then make the cleareſt and the moſt lively White, which becomes imperfect only in proportion as it's Tracks are diſcompoſed or not collected. After having, by means of a round Magnifying-Glaſs, call'd a *Lens*, united all the Rays that come from the Priſm, and gather'd them on a Piece of Paſt-board, into a very ſmall round Spot of the higheſt White; with a Ruler cover that Part of the Lens, on which you obſerve the blue Rays to fall, and the little white Spot becomes yellowiſh, or of a dull and dirty White Put the Ruler on the Part of the Lens where you ſee the red Rays enter; the Spot then begins to become bluiſh. From the Combination of the ſeven chief Colours, and of their ſeveral Degrees differently blended, the Grey, the Brown, the Olive, &c. the Slate colour, and all the other ſubordinate Colours proceed. The Black is not in Nature. It is Nothing. It is a Privation of reflected Light; and the leſs Reflexion there is, the deeper is the Black. But we may much better conceive, how we are to judge of it, when, after having ſeen the Rays themſelves, we ſhall have dwelt a Moment on thoſe Bodies, which reflect them, and which we ſhall call colour'd Bodies.

Coloured Bodies.

The Elements, of which the large and ſmall Surfaces of Bodies are made, muſt be conceived as Laminæ of an extreme Smallneſs, of a different Nature and Thickneſs, and to each other differently inclined. The Rays of the Light being in their own Nature quite different among themſelves, find not the ſame Relations and Diſpoſitions in all thoſe Laminæ, on which they fall. One Lamina, that will receive and refract the Yellow in its Pores, ſhall totally quaſh the Green. Another will partly admit a Ray, and partly reflect it. A third, which in a certain Degree of Inclination would have admitted and refracted the Purple, being differently placed and inclined, refuſes all manner of Paſſage to it, and reflects it entirely. At firſt Sight it is plain, that this may be diverſified *in infinitum*. Here a ſingle Inſtance may account for ten thouſand. A woollen Stuff is made up, as it were, of an infinite Number of ſmall Threads, themſelves made up of other Threads ſtill incomparably finer. By this Diſpoſition it is capable of reflecting all the Rays of the Light; which gives it the white Colour. But the Duſt inſenſibly ſticks to it, a Drop of Oil falls on one Place, ſome other Liquor is flung on another. Thus new Laminæ are convey'd into the Pores of the Wooll, whence follow Reflexions of ſome certain Rays, which being alone in that Place, interrupt the Whiteneſs, and form a Spot, by the Interruption of the Uniformity of the reſt of the Surface. You ſcower that Cloth. You cleanſe it from theſe heterogeneous Laminæ, and give it its former Whiteneſs. If you dye that Cloth, what do you to give it a new Colour? The whole Art of the Dyer amounts to only repleniſhing the Pores of this Cloth with Particles ſeparated from the Cochineal, the Grain of Scarlet, or any other Matter, of Service that way. The Multitude of the new Laminæ, which they throw into it, and which they know how to make to ſtick cloſe thereto by means of Allum, &c. is ſo great, that the whole Surface and Inſide of the Stuff are impregnated with them. And all theſe Laminæ of an uniform Structure, being fit to admit within their Pores all ſorts of Rays, except, for Inſtance, the red ones; the Stuff in this Caſe ſhall reflect none but the Red; and that in a certain Degree of Strength, or with a Mixture either of Purple or of other Tints. It will either be a Scarlet-red, a Crimſon dyed in grain, a Cherry colour, a Roſe-colour, a Fleſh-colour, or any other reddiſh Colour whatever. 'Tis true, there remain always in that Stuff ſome Laminæ fit to reflect green, blue, or other Rays; and this is ſo very true, that if you offer to a Scarlet-cloth, or lay on a blue Stuff, a yellow Glaſs, that is, one mix'd with ſmall Laminæ fit to admit every way a great number of yellow Rays, then either the blue or red Stuff ſhall contract a yellowiſh Colour, whereas the ſame yellow Glaſs being applied to a yellow Stuff, ſhall much heighten it's natural Colour. For a like Reaſon it is, that a Cray-fiſh, from the greeniſh Colour it had when alive, becomes red when boil'd. The Fire, which penetrates the Cray-fiſh, carries off from the Pores of it's Shell the Laminæ of Oil, Salt, *&c.* that fill'd them, and it brings forth Laminæ fit to reflect the red Rays, and to abſorb all other. The Stuffs you call changeable Stuffs are made up of a Warp of one Colour, and a Woof of another; whence it happens, that we ſee both Colours ſhine therein, either ſucceſſively or together. The Neck of a Pidgeon, a Pheaſant, or any other Bird, is cover'd with Feathers, which have each a double Row of large Laminæ, every one of which is made up of a double Row of other ſmall and extremely thin Laminæ. The large ones are of a clean Texture, and cover'd with an Oil, which makes them ſhine. The other ſubordinate Laminæ make ſeveral different Textures. The Elements of theſe different Orders being differently porous, and differently ranged, of courſe reflect or admit quite different Rays. The Bird cannot move his Head ever ſo little, without preſenting to our Eyes ſometimes ſmall Surfaces fit to reflect Rays of a certain Kind, and ſometimes other Surfaces fit to reflect Rays of quite another Species.

We ſhall conclude theſe Remarks by the Black, and therein find the Confirmation of all we have ſaid. A black Surface is nothing but an Amaſs of porous Elements, or of Laminæ ſo univerſally pierced, that almoſt all the Rays in general are admitted and totally abſorbed therein; ſo that by reflecting ſcarce any of them, the Body becomes black, even ſo as to appear a Hole, and a deep Hollow rather than an Object. This we eaſily obſerve in thoſe colour'd Bubbles, which Children make with Water and Soap. The Salt, Water, and Oil, which make the Sides of the Bubble, are heavy Matters, inceſſantly ſinking down towards the lowermoſt Part; ſo that the Bubble grows extremely thick there, while it grows very thin upwards. As the Elements, which compoſe the upper Part and Sides of the Bubble, become thin and tender, they reflect Colours livelier, finer, and of a more pleaſing Delicacy; but they become ſo very thin towards the upper Part of the Bubble, that they admit the Light entirely, and reflect not the leaſt Ray; which ought to make that Place appear quite black; and ſo, indeed, it happens. There ſeem to be pretty large Holes at the Top of the Bubble; becauſe the Sides, which are ſtill real and entire in it, reflect no longer any Rays, are no more perceived; and the whole Bubble burſts the next Inſtant after.

Colours are then eſſentially different in us, in the Light, and in colour'd Bodies. In us they are ſo many entirely different Senſations, wherewith God intimately affects us, in order to diſtinguiſh the Appearances, under which he preſents all the Parts of the Univerſe to us. In the Light, Colours are ſo many plain Strokes perfectly diſtinguiſhable from each other; but which, beſides their primitive Variety, ſtill form, by their ſeveral Mixtures, an infinite Combination of Changes and Gradations. Colours, in ſhort, are very different in Bodies themſelves; and beſides the Variety of the Apearances, there is an abſolute Foundation in colour'd Bodies, to affirm of one, that it is truly red; and of the other, that it is blue or yellow; ſince the ſmall Particles, which reflect one of theſe Colours, are, by the Inequality of their Structure, of their Denſity, Delicacy, Combination, and Inclination, very different from thoſe Elements, which compoſe a Surface of another Colour. The ſmall imperceptible Particles of the Surfaces of all Bodies are ſo many Sieves, which, as it were, ſift the Light. The Rays, which may be received and admitted through the Pores of one of thoſe Sieves, may be rejected by another. The White is a very fine Sieve, that ſuffers nothing to paſs through. The Black is the coarſeſt of all, which lets every Thing through. For this Reaſon it is, that a ſingle Sheet of perfectly white Paper, covering the Hat of a Traveller, or the Cap of a Child that walks, ſaves him from exceſſive Heat, by reflecting it into the Air. For the ſame Reaſon it is, that black Stuffs, and all black Bodies, are ſooner heated, and eaſier burnt.

Here Phyſics offer themſelves with all their Syſtems, to make us conceive, by what Mechaniſm the Subſtance of the Light performs all theſe Wonders. One Hypotheſis pretends to account for each of them, by making the Globules of the Light of Particles of unequal Sizes; ſo that the biggeſt ſhall form the Red, and the ſmalleſt make the Purple; and in order to ſupport their Suppoſition, they have recourſe to the Violence of the Red, which fatigues the Eye, while the Violet affects it but very moderately. Another Syſtem pretends to extricate itſelf better, by giving the Globules of the Light, or their Particles, different Degrees of Swiftneſs. Another, being afraid of altering by theſe Inequalities the Equilibrium eſſential to Fluids, will needs have recourſe to a Diverſity of Figures in the Particles of the Light, and in the Pores of the Surfaces ſtruck by them. Many other Syſtems may be deviſed and thought of. It is fit we ſhould liſten to them all, and be bigotted to none; not only becauſe there is no Explication, that can account for all we ſee in Nature; but becauſe we are not ſure, that the Mechaniſm, which appears to us the moſt probable, be exactly what the Almighty made uſe of. But the Benefit we may reap from thoſe little Syſtems invented by Men is this; that though there were in Light no other than the Artifice we endeavour to conceive therein, (and no doubt the Artifice we thus imagine is far inferior to Reality) yet does it always hold true, that there is in Light no Globule or any Particle, but what has received its proper Shape and Weight, its Degree of Swiftneſs, its Place and appointed Courſe. Whatever Syſtem and Oeconomy we may be tempted to eſpouſe, in the one as well as in the other, it is evident from the Regularity of the Effects, that all theſe Particles of Light have received Orders peculiar to them, and which they moſt faithfully execute. They march together, but every one in its Rank. One never anticipates the Right of another. In ſome Caſes, they are to go without Diſtinction, and to enter Bodies pell-mell. In others the Precedency is fix'd between them. When they go ſeparately, in entering the Red always goes firſt, and the Orange and other Colours enter in their

Turn, but Side-ways, and with Deviation, as it were, or a Glance. The Purple always takes the laſt Rank of all. The Order of their Return is no leſs regular. When theſe Colours fall on a Surface, which can admit them all, and at the ſame Time the Obliquity, under which they fall, begins to be great; the Purple rebounds the firſt, and no longer paſſes through the Surface. The Indigo follows next, and the other Colours do the ſame, as the Obliquity increaſes. The Red continues its Courſe longer, and is the laſt reflected.

From what has been juſt obſerved we conceive, that God, who alone was able to form the exterior and ſenſible Surface of all organized Bodies, has alſo taken care, in a Diſtribution truly immenſe, to regulate the Form, the Thickneſs, and Order, of the very minuteſt Elements, of which their Maſſes are compoſed; that the Shape and Interſtices of thoſe minute Elements might preſerve a juſt and an exact Proportion, with the ſuperlative Minuteneſs of the Particles of the Light; and that theſe Particles, being themſelves of ſeven different Kinds, they might ſometimes rebound from theſe ſmall Elements, ſometimes croſs their Interſtices, and thus produce Effects always new and regular. From this noble Oeconomy, eſtabliſh'd in the Senſations, which our Souls experience; from that Order we juſt now admired in the Structure of the Rays of the Light; in ſhort, from that, which we cannot refuſe to acknowledge in the very minuteſt Elements; I ſay, from theſe three Orders, eſtabliſh'd one upon another, and indeed uſeleſs without each other, the Sight and Uſe of Nature do reſult. For whoſe Sake were ſo many Cautions, and has all this Care been taken?

THE SHADE.

DIALOGUE X.

ALL Bodies, expoſed to the Aſpect of the Sun, receive their Light and Colour from him. We moreover ſee theſe Bodies attended by a Shade inſeparable from them, and which may in its Turn deſerve our Reflections. Shadow is not, like Darkneſs, a Thing of nought. It is attenuated Light; a more or leſs conſiderable Diminution of the Light, reflected from the Surface of Bodies, in a Place, to which the Sun cannot directly throw its own. Laws invariable and as antient as the World, cauſe that Light to daſh from one Body upon another, and from this ſucceſſively on a third, and ſo on, like Water in a Caſcade, but always with new Diminutions of Force from one Fall to another. Were it not for theſe all-wiſe Laws, whatever is not immediately, and without any Obſtacle interpoſed, under the Sun, muſt be enveloped in total Darkneſs. While the Sun chears the Eyes of thoſe, who are in the Court of a Building, thoſe, who have a mind to view the Inſide, or the oppoſite Front of it, would on a ſudden be wrapp'd in the darkeſt Obſcurity; and the Tranſition from the enlighten'd Side of Objects to that, which the Sun does not ſhine on, would, throughout Nature, be like the Paſſage from the Surface of the Earth to the Inſide of Vaults and Cellars. But by an Effect of the powerful Springs, which God ſets a-going in every individual Particle of that thin Subſtance, it puſhes all the Bodies, on which it falls, and is repell'd thereby, on Account both of its Spring and the Reſiſtance it finds from them. It daſhes on and bounds from the Bodies it has ſtruck and brighten'd by its direct Influence. From theſe it is carried on to thoſe round about; and though it thus paſſes from the one to the other with a continual Loſs, it ſhews us even thoſe not expoſed to the Sun. From one Surface to another, and from turn to turn, it at laſt reaches the remoteſt Receſſes; and when it can no longer there procure us the diſtinct Sight of Objects, it ſtill ſhews them us confuſedly; it at leaſt prevents our tumbling, and informs us of all Dangers.

What the whole Maſs of Blood does in Nature in great, by changing itſelf into a Twilight after Sun-ſet, each individual Ray of Light does at every Inſtant, in transforming itſelf into a Shade by its ſeveral Daſhings. Any Portion of Light, which has already been of Uſe to us, inſtead of ſuddenly ceaſing to be of Service, on the contrary prolongs and even varies it, as it grows weaker. Theſe ſeveral Degrees of Force rule our Actions, and ſuit themſelves to our Wants. The great Beauty and lively Splendor of the pure Light, make us ſet our Apartments towards the Sun, from whom our Life and Health proceed. The darkeſt Side will ſerve to lay up in Store ſuch Things as ſhun the Heat or a glaring Light. The Shade ſerves us to judge of the Situation of Objects, as well as to be the more ſenſible of their Diſtances; it ſerves to diſtinguiſh Things, which are like; it ſeems to make two different Colours of one, by taking from it the Brightneſs it had in the broad Day-light. The Scarlet ſeems to change its Nature, when it comes into the Shade; it will undergo another Alteration, when it enters into a Shade that is deeper. All Bodies, even thoſe of the brighteſt Colours, become darker, as they decline from the Influences of the Sun, and from the firſt Reflexions of the Light, which conveys every where uſeful Differences. For in ſetting off an Object by the Help of a Ground, or of another Object, next to it more or leſs dark, it embelliſhes, characterizes, and diſtinguiſhes in our Eyes, what the Remoteneſs or the Uniformity of Colour would have confounded.

The Shades in Painting.

It is the Study of that Mixture, and of thoſe gradual Attenuations of the Light and Shades, which makes one of the nobleſt Parts of Painting. In vain ſhall the Painter know, how to compoſe a Subject, to place his Figures, and to draw the whole in a correct manner, if he knows not, by the Attenuations and exact Degrees of Light and Shade, how to make ſome Objects draw near, others to ſit back, and to give them all their Contours or Out-lines, their Diſtances and different Degrees of Strength, and the Appearance of Reality and Life. Draughtſmen or Deſigners, to expreſs their Thoughts, only uſe weaker or ſtronger Shades.

In Engravings.

Engravers, in order to multiply the Copies of the nobleſt Pictures, uſe no other Colour than the White of their Paper, which they convert into as many Objects as they pleaſe, by the Strength and Degrees of Shade they cover it with; or elſe, they do the Reverſe, and

Engraving in Mezzotinto.

furrow the whole Copper-plate with large Strokes; ſo that the Paper they ſhould apply thereto, when blacken'd, would, from the Preſs, preſent nothing but an uniform Shade, or an univerſal Black. They afterwards ſcratch or burniſh out of their Plate, more or leſs of theſe Strokes. The weaken'd Parts of the Shade become ſo many Points of the Object; and the more theſe Points of Shade are flat and well erazed, the ſtronger and the better heighten'd are the Lines of the Object.

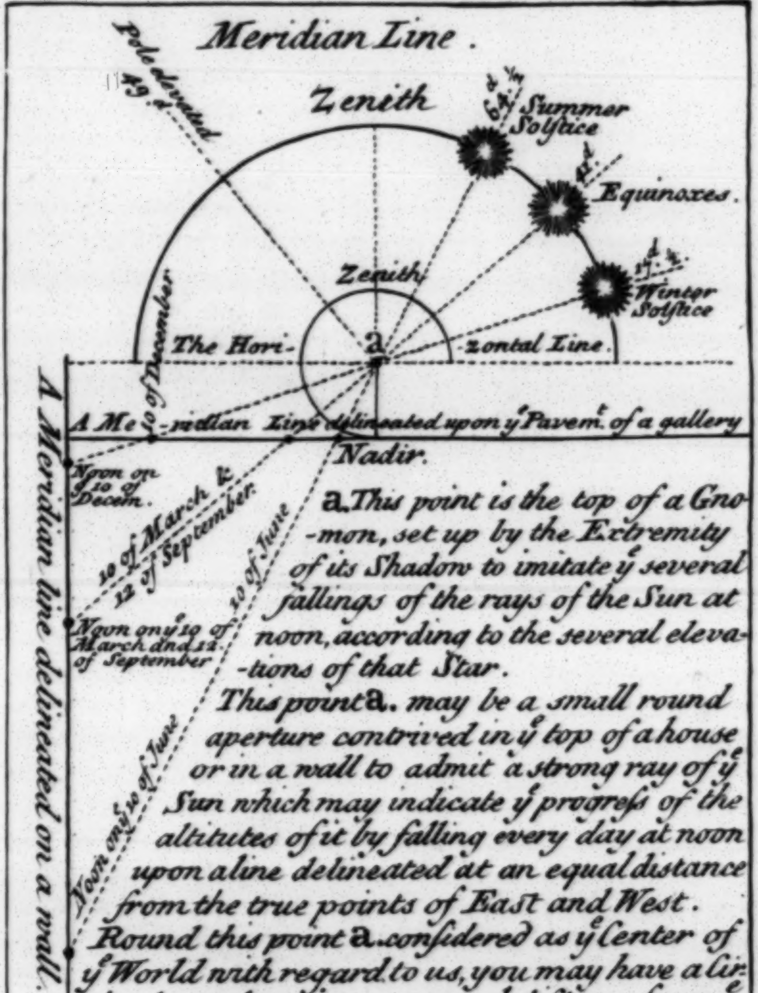
The Coolneſs of the Shade.

Beſides the important Service of conveying a greater Diſtinctneſs in the Picture of Nature, the Shade conveys with it every where another far greater Advantage, I mean, Coolneſs. This, with regard to Cold, is what Shade is to Darkneſs. Cold is no more than the Abſence of Heat, as Darkneſs is only the Privation of Light; and as the Shade does not take the Uſe of the Day from us, the Coolneſs, which attends it, does not deprive us of the Uſe of a mild and moderate Warmth.

As the Summer comes on, and as the Coolneſs becomes neceſſary, God ſpreads and thickens the Shades, which procure it for us. He gives Strength to the Leaves, and prepares convenient Coverts, under which the drooping Flocks ſhun the Beams and Heat of the Sun. Man comes thither to refreſh his exhauſting Spirits; there he enjoys the Cool, without being in the Dark; there he continues his Work, without being deprived of the Sight of Nature. When the Return of Winter ſhall again bring him to the Chimney-corner, then ſhall the Leaves become uſeleſs to him; and then is the Time of their Fall; but Man ſhall ſee them ſpring again with his renew'd Wants.

Gnomonics, or Dialing.

That Shade, ſo uſeful in its own Nature, becomes ſtill more ſo by the Induſtry of Man, and by the Attention he gave to the ſeveral Uſes it was of. When he ſees it follow exactly all the Situations of the Sun; or rather, when he obſerves, that the Motions of the Shade are the ſame as thoſe of the Rays, which would fall on the Ground, were they not interrupted in their Courſe; he informs himſelf of the Path of the Sun, by that of the Shade; he makes the Shade of a Pyramid, a Style, or a Column, to fall on Lines and on Points, where it ſhews him at one View, and without a Trouble on his Part, the Hour of the Day, the Elevation of the Sun above the Horizon, and the exact Point of the celeſtial Sign it actually is in. The Reaſon of this Practice is eaſy to be conceived. Imagine in the Heaven a Point exactly over our Head, and which we ſhall call *Zenith*, after the *Arabians*, who, next to the *Greeks*, were our Maſters in Aſtronomy, and have fix'd the Terms of it. Let us ſet up a Pyramid, or a ſimple Pole perfectly perpendicular; and let us extend it in Imagination up to the Zenith, by a perpendicular Line reaching from one to the other. If the Sun ſhould come to the Zenith, one of its Rays would fall down that Perpendicular on the Pyramid; the Point of which oppoſing to that Ray, no greater Obſtacle on one Side than on the other, it would form no Shade, But if the Sun deviates from the Zenith, its Ray falling obliquely on the Top of the Pyramid, the Point of Shade made by its Top on the Earth ſhall be diſtant from the Foot



a. This point is the top of a Gnomon, set up by the Extremity of its Shadow to imitate yͤ several fallings of the rays of the Sun at noon, according to the several elevations of that Star.

This point **a.** may be a small round aperture contrived in yͤ top of a house or in a wall to admit a strong ray of yͤ Sun which may indicate yͤ progreſs of the altitutes of it by falling every day at noon upon a line delineated at an equal distance from the true points of East and West.

Round this point **a.** conſidered as yͤ Center of yͤ World with regard to us, you may have a circle whose plane is at an equal diſtance from yͤ East and yͤ West; and thereon take degrees that may be with regard to the Nadir or the inferior point, what yͤ several altitudes of yͤ Sun are with regard to the Zenith.

The lines drawn from the center **a.** upon these points, and prolonged to the Meridian line shall point out there upon the several fallings of the rays of the Sun, according to his elevation.

Ja. Mynde Sculp.

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of the Pyramid, in Proportion as the Sun ſhall be diſtant from the Zenith, and the Length of the Shade may then be call'd the Diſtance of the Sun from the Zenith for that Day. If the Length of the Shade varies from Day to Day, at the Moment of the Sun's greateſt Elevation, when he is in the Meridian or at Mid-day, it may be calculated how much the Sun draws near or recedes from the Zenith in the Compaſs of a Year. That Shade on the 21ſt of *June* N.S. is the ſhorteſt, and on the 22d of *December* N.S. the longeſt it can be in the whole Year. All theſe Points of Shade faithfully obſerved and mark'd, ſhall then be the faithful Image of the ſeveral Situations of the Sun in the Heavens, and the ſucceſſive Inequalities of that Shade ſhall expreſs the Succeſſion, Order, and Limits, of the Courſe of the Sun.

Sun-Dials. A Meridian-line.

Inſtead of the Shade we may make uſe of a brisk Ray of Right through a Shade or Hole, which comes, and with its Extremity whitens and marks out among Points and Lines drawn on the Ground or otherwiſe, the Place, which relates to the Progreſs of the Day, or of the current Month. Some uſe a ſmall round Aperture in the Cieling or the Wall, having a ſouth Aſpect, on a Pavement or an inlaid Floor. They lay on that Pavement, rather than on the inlaid Work, which the ſultry Heat or the wet Weather always injures, a Lamina of Marble or of Copper, which directs its Extremities towards each Pole. This Line is call'd a Meridian-line; becauſe it neceſſarily takes in all the Points, on which the Ray of the Sun will fall every Day of the Year, at the Inſtant when that Star is equally diſtant from the Place of its Riſing and that of its Setting. And as it riſes or goes down differently in the Heaven, according to the Seaſons of the Year; the Point of Mid-day, though always received upon that Lamina, falls thereon higher or lower, according to the Situation of the Sun. This Variety is there expreſs'd by ſo many Marks, which point out to you and exactly diſtinguiſh the Solſtices, the Equinoxes, and the daily Diſtances of the Sun from the Æquator, towards either of the two Tropicks, between which its Courſe is confined.

Such is that famous Line, which *Egnatio Dante*, a Dominican or White Friar, delineated in the Church of *St. Petrone* of *Bologna*, *Ann.* 1575, to mark out chiefly the Points of the Solſtices and the Equinoxes, the Non-obſervance of which had diſcompoſed the Order of the Holy-days. That Line was placed in ſome other Part of the ſame Church, and infinitely improved by the great *Caſſini*.

Of this ſort is the Meridian-line delineated at the Royal Obſervatory. Such are all thoſe, which private Perſons now make in their own Studies, or in any other Place, the better to regulate their Pendulums.

The dark Room.

A quite different Uſe of the Shade, or rather of the Light ſurrounded with the deepeſt Darkneſs, is commonly made. They put upon a Table a ſort of little Room or Tent, ſupported by Laths, and well cloſed with good ſtrong Cloth. That Tent, which moſt commonly is made in Form of a Pyramid, is terminated by a large Glaſs of a lenticular Form, above which are two ſmall Uprights, deſign'd to ſupport, and at Pleaſure to incline a flat Looking-glaſs. The Rays of the Objects from every Side fall on that Glaſs, whence, by the juſt Diſpoſition given them, this Looking-glaſs being inclined ſo as to form an Angle, *&c.* they are reflected on the lenticular Glaſs, horizontally placed at the Top of the little Room. That Glaſs, which is thicker in the Middle than at the Edges, refracts and draws theſe Rays near each other, ſo that they paint in Miniature the Image of Objects on the Bottom of the Room, wherein a Linnen-cloth or a white Paper is laid, in order to give them more Strength. If you turn your Back to the Objects, and put your Head under the Fore-curtain, but in ſuch a Manner, that the Light cannot get into the Tent, the external Objects ſeem painted there with all their Colours. It is not poſſible to ſee a more exact Proſpect or Landskip whatever. It is Nature itſelf.

This pretty Invention goes farther than mere Amuſement. We may very uſefully exerciſe ourſelves in delineating on a Paper the Lines, which terminate, or the Out-lines of the Objects. We may place at the proper Diſtance a Perſon, whom we order to put himſelf in this or that Poſture, or take ſuch or ſuch an Air of the Head, and any other Attitude we may want. And it is not only an eaſy Matter to exerciſe one's ſelf in the moſt difficult Parts of Drawing; but we ſhall likewiſe in a very ſhort time take the Profile and Proſpect of a Caſtle, of a Landskip, or of a large Town with its Towers and Steeples. By this Means, you are ſure of the Exactneſs of the Figures and Situations. You afterwards take the Time neceſſary to ſhadow each Piece, according to the Degree of Force it ſhould have, or to colour the whole, without loſing Sight of the Original you copy after. Thus Nature proves the moſt learned and moſt convenient of Maſters to us.

It is an eaſy Matter to make of Shade another, indeed leſs entertaining, but ſometimes more neceſſary Uſe. You have a Mind, without giving yourſelf any Trouble, and without any Inſtrument, to know the Height of a Tree, a Building, a Steeple, or a Hill. The Shade of theſe Objects will immediately acquaint you with the Truth of the Matter; provided you don't make the Operation immediately after the Riſing or before the Setting of the Sun; becauſe the Shadow at that Time ſhortens or lengthens ſo ſuddenly, that there would be a Miſreckoning from one Moment to another.

To know the Height of a Tower by its Shade.

Thruſt into the Earth a Stick perfectly upright and perpendicular. Meaſure the Shade of it. This is either longer, ſhorter, or equal to the Stick. It will be with the Shade of the Tower compared with the Height thereof, as with the Shade of the Stick compared with the Height of the Stick itſelf. Meaſure the Length of the Shade of the Tower, which ſuppoſe you found to be twelve Fathoms. After having in the ſame Manner meaſured the Shade of the Stick, divide this laſt Length into twelve equal Parts, which we ſhall call Inches, Minutes, or any other Name you pleaſe. By applying that Meaſure to the Stick, you, for Inſtance, find that it is but ten Inches, or ten of thoſe equal Diviſions or Parts. This being ſo, the Shade of the Stick is of Courſe two Inches longer than the Stick itſelf. The Shade of the Tower does then likewiſe exceed the Height of the Tower by two Fathoms, and thence you are unqueſtionably inform'd, that the Tower is ten Fathom high. If, on the contrary, the Shade of the Tower happens to be eight Fathoms, and the Stick to exceed by two Inches, or Parts, its own Shade, which you ſhall have divided into eight equal Parts, it thence follows, that the Tower is by two Fathoms higher than its Shade is long. It is then ten Fathoms high. Finally, If the Stick is equal to its Shade, and the Shade of the Tower, immediately meaſured, proves to be ten Fathoms, you may, without any other Calculation, be certain, that the Tower and its Shade are equal, and that its Height is ten Fathoms.

This Compariſon of the determined Height of a Pyramid, or any other Gnomon, (or Object ſet up, to inform us of ſomething by its Shade) affords us an excellent Method of fixing certain Points of Geography. For Inſtance; if we know, from faithful Memoirs, the Proportion, which is at *Pekin*, between a Tower a hundred Foot high and its Shadow, on the Day of the Summer Solſtice at Noon, and at the ſame time find another Proportion at *Paris*, between a Gnomon one hundred Foot high and its Shade; from the Difference of theſe Proportions we are inform'd, how much *Pekin* is nearer than we to the Line, which bounds the Courſe of the Sun. For the nearer a Place is to the perpendicular Fall of the Rays of the Sun at Noon, the ſhorter likewiſe the Shade of Towers proves there to be. We may then judge how much nearer one Town is to the Point of the Solſtice than another, from the Inequality of the Shade of two Towers of the ſame Height under the Meridian Sun of any particular Day.

Though Man's Skill contributes ſomething to theſe ſeveral Operations; it conſiſts only in obſerving the Motions of the Light, and in making uſe of the Helps, which Light affords us. The Fluid, wherein all theſe Lines and ſeveral Directions ſubſiſt, touches us immediately. But the Source of the regular Motions for our Sake operated therein, is thirty three Millions of Leagues diſtant from us.

THE

THE PLACE and USES OF FIRE.

DIALOGUE XI.

GOD, by the manner, in which he has conſtructed and placed the Sun, has made it the Centre of the Diſpenſation of that Day and thoſe Colours, which were to render the World viſible. But his profound Wiſdom, which delights in bringing a Multitude of great Effects out of one and the ſame Inſtrument, has deſign'd moreover the Activity of that wonderful Globe, to diſtribute throughout the Earth the juſt and exact Quantity of Heat, which therein gives Life to Man, Animals, and Plants. 'Tis true, Heat can create nothing. Organized Bodies are not indebted to it for their Structure; and the Elements, which nouriſh and make theſe organized Bodies to grow, have alſo their peculiar Nature independent from Heat. But it is with good Reaſon, that Heat is ſtiled vivifying; ſince God has appointed it, to ſet the Elements at work, and to aſſiſt organized Bodies in their Unfolding, Growth, and Perfection. It is that Heat, which gives Birth to the Winds, by dilating the Air. It is that, which, by raiſing the Water on high, every where conveys Coolneſs, Refreſhments, and Plenty. It is that, which makes Men long for enjoying the Sun, ſince it is that Star, which ſecures them not only fine Days, but even their Breathing and Life. We all of us, without the Help of any Arguments or Inquiries, are ſenſible of the ſecret Relations, which are between the Heat of the Sun and our Life. We value our Habitations, only as they enjoy the Aſpect and Influences of that Star. We have no Opinion of, and diſtruſt ſuch as are by him but obliquely influenced. When they are totally deprived of it, we compare them to Tombs. And it is becauſe the Sun warms whatever it lightens, that we ſtyle it the Soul of Nature.

But let us not entertain of him an Idea more advantageous than Truth will admit; and let us be ſure not to fall into the ſame Miſtake as thoſe Nations and Philoſophers did, who honour'd it as the Father of Light and Fire. In the greateſt Remoteneſs of the Sun, and in the darkeſt Night, we ſtill have the Uſe of Fire at our Command. There may be then at leaſt one ſort of Fire, which we do not always receive from him the Moment we uſe it; and it will perhaps be the ſame with the Fire or Heat, which we experience in Preſence of the Sun, as with the Light itſelf. We have remark'd, that the Light was not any Emanation of the Subſtance of the Sun. That it was before him, and not in him. That it was as effectually round us during the Night, wherein the minuteſt Spark of Fire renders it ſenſible to us, as it is in the broad Day-light, when the Sun puſhes it violently upon; in ſhort, that the Sun was not, any more than a ſingle Spark, the Mover of the Body of the Light. Though the Light ſhould in itſelf then be a real Fire, the Sun, which puſhes it towards us, would at moſt be only a magnificent Inſtrument, deſign'd to communicate to a great Diſtance the Uſe of the Fire, by the Univerſality of the Impreſſion it gives the Light; and we ſhall always be forced to look higher than the Sun for the Principle of that immenſe Action, and the Original of this noble Oeconomy.

But the Intention, which has form'd theſe Springs, and the Hand, which governs them, ſhall become more ſenſible to you; nay, you will needs be amazed, at the Conſideration of the Cautions that were employ'd to ſecure the Length of our Days, when I come to ſhew you, that beſides the Light, which fills the Univerſe, God has placed near us, and purely for our ſake, as well in the lower Strata of the Air, as within the outer Cruſt of our Earth, an Element full of Force and Activity, which we ſhall call the Terreſtrial Fire; that it is that Fire, which is the conſtant Support of our Life; that it owes it's Exiſtence neither to the Sun or to the Light; and that what it receives from the Sun, amounts to no more than a ſtronger or weaker Impulſion, which it receives from it by means of that Fluid the Light, which extends from the one to the other.

To avoid all Diſputes, I ſhall grant, if you pleaſe, that Light is a real Fire, and that it can both burn and give Light, in proportion as it's Activity or the Impulſion it has received is greater. You may call this the Celeſtial Fire, if it burns by itſelf, and not by means of our Fire. But it ſeems to me evident, that there is a Terreſtrial Fire, a very near Neighbour to us; that it enters more or leſs into the Compoſition of terreſtrial Bodies; that it is diſperſed through the whole Maſs of the Air, eſpecially of the lower Air; that it is not perceptible in terreſtrial Bodies, ſo long as it remains impriſon'd therein; that it is not viſible in the Air, ſo long as it is in Equilibrio, and equally diſtributed therein; but that it breaks out, when it is agitated or confined; in ſhort, that, far from being the Light, it has the ſingular Property of being puſh'd and acted on by the Light when agitated, and of making, in it's Turn, the Light to ſhine by repelling it. I ſhall rather make uſe of Matters of Fact than Arguments, to convince you of thoſe extraordinary Means, by which God preſerves Mankind, and in which we find the affecting Proofs of a kind Benevolence, which could have no other Object than ourſelves.

1. We may experience a very gentle Warmth in a very dark Place, and convey the brighteſt Light through the Windows of a Room wherein we feel an exceſſive Cold.

2. The Fire, which comes out of a *German* Stove, ſenſibly affects us, without making the leaſt Impreſſion on the Eye, otherwiſe ſo eaſy to be affected; becauſe that Fire, though abundant, is much diſperſed, equally diſtributed, and incapable of puſhing the Light upon our Eyes; except where it is agitated, confined, and accelerated. On the contrary, the Light reflected by the Body of the Moon makes a ſtrong Impreſſion upon the Eye, without having however the leaſt Heat. Here is then a very plentiful Fire without Light, and a very bright Light without Heat.

3. But it is an eaſy matter to diſunite the terreſtrial Fire and the Light ſtill more. Let us place ourſelves on the Top of the *Alps*, or on the *Pico* of *Teyde* in the Iſland *Teneriffe*, nearly at the Entrance of the Torrid Zone; or rather ſtill on the Top of the *Cordilieras* in *Peru*, which is in the very middle of the ſame Zone, and on the higheſt Mountains in the Univerſe. You imagine, as you aſcend, and more and more approach towards the Sun, that you are are going to experience a greater Heat. But I adviſe you not to venture that Journey ſlightly cloth'd; for I muſt tell you, you will be not abſolutely free from ſhivering under the warmeſt Fur-lining. The more you ſhall aſcend, the ſharper will the Cold appear to you. The Air of the *Pico*, under the twenty-eight Degree of Diſtance from the Æquator, is ſharper, though without Wind, and in the Month of *Auguſt*, than the Air of *London* under the fifty-ſecond Degree of Latitude, and during the hardeſt Froſts that were ever experienced there. This Fact, atteſted by very credible Witneſſes *, begins to hint, whether the Body of the Fire comes from above or reſides below. But as you might be inclined to think, that the Reflexion of the Plains makes up the Force of the Light; inſtead of a Mountain terminating in a Point, let us chuſe the *Cordilieras* of *Peru*. You are not to imagine them ſo many irregular Pyramids. We on the contrary find there very ſpacious Plains ſeveral hundreds of Leagues in Length, and which being higher than the

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* The Air, at the Top of the Pico, was as cold as I have known it in England in the ſharpeſt Froſt I was ever in. Extract from the Relation of the Voyage made to the Top of the Pico, by M. J. Edens. Philoſ. Tranſact. abridged. Vol. 5. Part ii. Pag. 147.

Region of the Clouds, and of the terreſtrial Vapours, are chear'd with a pure Light, which muſt needs be there very active and powerful, ſince it every Day falls thereon almoſt perpendicularly. No Wind comes thither to weaken, or any Fog to blunt it. Nothing, in ſhort, is ſo brisk as the Reflexion of that Light. Thoſe Places however are deſtitute of all Heat. It cannot ſo much as melt the Snows, which lie lower on the Declivities, or aſſiſt the Production of any Plant whatever. No Traveller ever ventures on this dangerous Journey, without covering himſelf as warm as he would be in the North. He ſometimes is frighten'd on finding Men on Horſes dead with Cold, which continue ſtiff and unchanged for ſeveral Years together, in Places perfectly inacceſſible to Heat, Rain, and Inſects.

Were the Light the ſame Thing as our Fire, the Heat always would increaſe in proportion to the Light, when it is not croſs'd by the Wind, or intercepted by any Clouds. Here is however an extremely brilliant and perfectly reflected Light, which yields but little, or rather no Heat at all. I have then ſtill the greater Reaſon to think, that if the Light, which we receive in our Climates, is therein accompanied with great Heats, is it becauſe it puſhes towards us a Fire, which it finds there, and which is not ſo abundant in more elevated Places.

4. And really, as I deſcend from the Top of theſe cold Mountains, (and we find the ſame thing alſo in coming down the *Alps* and the *Apennine*) I breathe a milder Air. I proceed to Places where the undermoſt Snows begin to melt, while the uppermoſt remain impenetrable to the Light, how bright and glaring ſoever it may be. As I come ſtill lower, I perceive a little Graſs, and the Fertility increaſes together with the Impreſſions of the Heat. Soon after I walk a-croſs Herbage and Woods; and at laſt I am (though the Sun be but juſt up) obliged to rid myſelf of the Burden of my Cloaths, which overweigh me, whereas they ſcarce could ſhelter me againſt the ſharp Cold of the upper Grounds. The Change I experience, as I draw nearer the plain, is then in the Fire itſelf and not in the Light. The Fire abandon'd me before, as I went from the lower Lands, and every

thing, as it were, invite me to acknowledge it's reſiding there.

My firſt Suſpicion gathers Strength from other Experiments. A burning Coal, which, being offer'd to the Focus of a ſpherical concave Glaſs, darts it's Heat by parallel Rays on another Glaſs placed at forty, or even fifty Paces Diſtance, ſends thither a ſufficient Number of them, by a reflex Fire, to burn a few combuſtible Matters, in the Focus of this laſt concave Glaſs; whereas the Light of the Moon, heighten'd by the Re-union, and giving in the focal Point a Degree of Brightneſs, which Meſſieurs of the Academy of Sciences judge to be five hundred times greater than that of the Full-Moon, warms nothing there, nor does ſo much as cauſe the leaſt Agitation imaginable in the Liquor of the Thermometer, which even the Approach of the Hand is capable of raiſing. A very little Fire then diſplays a greater Capacity for burning, than a very great Light does; and who knows but the Light does not burn by it's own Power, but by the Mediation and Interpoſition of the Fire it puſhes forth, when it is come up to a certain Degree of Activity, or when being bent in the Convexity of a Glaſs, it unites it's whole Force in a ſingle Point, and there ſtrongly quickens the Fire it meets with, becauſe this reſides in the Air?

Let us not degrade Light. Let us ſuffer it to enjoy the Reputation it has, of being able to warm and burn in proportion to it's Strength. How queſtionable ſoever this it's Prerogative may become, from the foregoing Experiments; it is enough that we have made it good, that there is a terreſtrial Fire, amidſt which we live, which becomes ſenſible, when the Light of the Sun preſſes on and puſhes it towards us, and which makes the Light ſhine in the middle of Darkneſs, when it is with Violence carried againſt it.

6. The Light without any Hindrance paſſes through Cryſtal, Glaſs, and Jewels. But moſt of theſe tranſparent Matters ceaſe to be ſo, the Moment the Fire penetrates through or makes them red; and that Fire, very far from being the Light, does then actually reflect and entirely repel it, without yielding it any Paſſage.

7. The Light of the Sun, which ſparkles with but very little Heat, even in the midſt of Summer, on Mountains, where it finds leſs Fire to preſs, ſo ſwiftly throws down upon us the more abundant Fire it finds in the lower Air, that it renders it furious, and makes us ſuffer ſultry Heats, even when it no longer ſhines above our Horizon, and when the Night is come. Was Light Fire, we ſhould have exceſſive Heats, before as well as after the Solſtice, and in *May* as well as in *July*. The Light, at the End of theſe Months, is equally briſk and active. That at nine o'Clock in the Morning, is the ſame as that at three in the Afternoon. But the firſt only begins to quicken the Fire, whereas the Fire violently agitated, ſtill maintains it's fury a good while after the ſecond is gone. The Light does then only irritate the Fire, and is not the ſelf-ſame Thing with it.

8. What makes us confound them is, the Cuſtom of ſeeing them almoſt never aſunder. Above all we are apt to believe, that a Stroke of Light is in itſelf a Stroke of Fire, when we ſee it paſs through a lenticular, or reflected from a concave Glaſs, and there burn or calcine what is offer'd to the Focus. But the Light is not of itſelf perhaps more burning in that Point than in any other. 'Tis true, it's Activity and all it's Efforts are center'd there. It prodigiouſly quickens the ſmall Quantity of Fire, which it finds there, and which, as it were, it keeps cloſely impriſon'd. It renders the Fire it finds there furious, but does not bring it thither; or if it there precipitates the Fire from ſeveral Points, yet that is no Argument why we ſhould confound it with the Light.

9. So many Proofs we have to produce, ſhewing that the Light is diſperſed throughout the Univerſe, and that it is preſent every where, even when it is unmoved, and in Appearance void of Action; ſo many of almoſt palpable Proofs have we to offer, ſhewing us, that that Fire has been placed for our Service, not truly above the Air, as *Ariſtotle* thought, or in the Light, as we may fancy from ambiguous Proofs, but in the lowermoſt Regions of the Air, in the Neighbourhood of the Earth, and in the Earth itſelf to a certain Depth.

Nor are you to think, that this precious Element, the true Support of the Life of our Bodies, (and who knows but it may be that Life itſelf?) be any way hinder'd in it's Operations, from it's having been placed in the groſs Air, in the Water, and in the Earth. How theſe Elements are conſtructed, I indeed know not. But what ſtrikes every attentive Eye is, that the Structure and Artifice of them is ſuch, that they unitedly produce the nobleſt Effects, and that oftentimes the one is perfectly void of Power without the Aſſiſtance of the other. Light increaſed accelerates the Motion of the Fire; the Fire collected dilates the Air; the dilated Air raiſes the Water, the Oil, and the Salt. All the Elements blended together roll in the Atmoſphere, whence they ſpread all over the Earth, and ſtrew Bleſſings every where. You ſee at one View the Conſequences of this wiſe Mixture.

Though perfectly impenetrable by our Underſtanding, it is demonſtrated by Matters of Fact; and it is in particular an unqueſtionable Truth, that the Element of Fire reſides in the Air we breathe, in the Water we drink, and in the Earth from whence we fetch our Food. The Air, which the Fire abandons in receding from the Earth, becomes intolerable. The Water, which the Fire does not ſupport, refuſes to flow for our Uſe, and by freezing becomes as hard as a Stone. The Earth, deſtitute of Fire, is a heavy-Maſs, void of Action and Utility.

The Fire dwells in the Bowels of the Earth, at leaſt to a certain Depth. It ruſhes out of it, through the Crevices and Openings of Volcano's. The Water carries it, together with the Sulphur, a great Way from the Iron Mines. It is waſh'd from them, and we ſee it iſſue together with the Mire of hot Baths. It is not leſs real, for it's apparent Inactivity in the Filaments of Sulphur, in Fat, in Woods, and in all vegetable Bodies. A briſk Shock diſcloſes the Fire, which reſides even in the Bowels of Flints, or at leaſt the Fire of the Air, which is catch'd between the two Points that ſtrike againſt each other.

The rubbing of Glaſs-tubes, or of the Axle-tree of a Wheel, not only heats them, by quickening the Fire, which makes a Part of their Subſtance; but even diſplays Particles of that Element, oftentimes capable of cauſing a Conflagration. Theſe Sparks, fetch'd either from Stones, or out of the Air, and violently agitated againſt each other between two Mill-ſtones without Corn between them, acquire a degree of Force capable of ſetting the Timber-work and the adjacent Buildings on Fire.

No Body is ſo apparently deſtitute of Fire, as Marble and Metals are, but what grow hot by violent Motions, not only by the Agitation cauſed in the Fire that ſojourns therein, but alſo by the Communication of the Fire, which is heighten'd in the agitated Air, and in the ambient Bodies. Claſhings and Shocks are not the Fire, but ſerve to let it looſe, by agitating or cruſhing the Bubbles of Air, and the little Cells, which contain it. All Bodies may be equally agitated or preſs'd; but all are not therefore equally combuſtible. They are the more apt to take Fire, as they contain a great Quantity of that Matter, and as that Fire, whoſe force conſiſts in it's Quickneſs, acquires a greater Motion by it's Agitation.

The Fire is then under our feet, and all around us, always ready to ſerve our Purpoſes; we loſe it in porportion as we get above the Plains, where God has fix'd our Dwelling; and it is a very pleaſing Conſideration for us to ſee, that in finding out the true Place of this ſo beneficial and ſo comfortable Fire, we at the ſame time find out ſo evident and ſo well diſtinguiſh'd an Intention in God, of placing it within our Reach, and of keeping it always in a readineſs to favour all our Deſires.

Theſe Proofs ſeem ſufficient, to make me renounce the common Prejudice, which confounds our common Fire with the Light; and though I conceive not the Nature of either of them, I ſhall ſufficiently diſtinguiſh between them, if I am but ſenſible of the Difference of the Place they take up, and of the Functions they are appointed to diſcharge.

The Fire and the Light then dwell around us, ſince in the Night, as well as in the Day-time, and without the Help of the Sun, we make uſe of them, and always find them at need. But the Place of the Fire, which we uſe, extends not to a great Diſtance from us. The Place of the Light, on the contrary, extends to the very Stars. The Activity of the Fire ſpreads but a little Way, and it ſenſibly ceaſes to act, when it is ever ſo little ſcatter'd. The Activity of the Light, on the contrary, extends to an almoſt infinite Diſtance. Theſe two Elements, when in Repoſe, and not outwardly influenced, keep between themſelves a ſort of Equilibrium. They touch without claſhing againſt each other; they are under our Hands, and before our Eyes, without being either felt or ſeen. But one of them cannot be ſtrongly agitated, without cauſing an Agitation to the other; and their reciprocal Power increaſes in proportion to their Quantity, and the Strength of the Impreſſion received. The Narrowneſs of the Compaſs, within which the Fire is accelerated, ſtill contributes to increaſe it's fury. The Fire in a *German* Stove cauſes no Conflagration in adjacent Bodies, nor any Emotion in the Light, as it is diſperſed at Liberty and in a true Equilibrio; whereas that ſmall Parcel of Fire we call a Spark, is ſo violently agitated between the Part of the Flint where it is ſtruck, and the Parcel of the Steel, which fetches it out, that it melts the Metal, and ſhakes the Body of the Light, ſo as to make it appear at a hundred Paces round it. We find theſe melted Particles of Steel in the Paper, over which we have ſtruck a Light. The Microſcope, which ſhews us their bright and unravell'd Figures, is a Proof of their having been in a State of Fuſion.

When then the Fire and the Light are in Equilibrio, their Quietneſs inſures our Eaſe and Repoſe. The Trouble of the one can no ſooner be communicated to the other, but they both acquire a Force deſign'd to procure us ſome Advantage, or to warn us of ſome Danger. The increaſed Light keeps the Fire from being unactive. Thence the Motion aud Fertility of Nature. The minuteſt Particle of Fire violently forced out of a Flint, receiving from that Shock a Force ſufficient to melt the Particle of Steel, which ſtrikes it out, has alſo a Force ſufficient to agitate ſtrongly the Light, which immediately communicates it's Agitation to us. Whence the perpetual Advices it gives us. When the Fire is but little, it is only a gentle Glimpſe.

But it's Splendor becomes terrible, when there is any great Danger. It ſeaſonably reveals all the Operations of that dreadful Element. It declares it afar off, and long before it's Arrival. It gives us warning of the Havocks it may make; and becauſe the Fire has a Fury capable of cauſing a general Deſtruction, it is, that the Light was placed near it, as a watchful Centinel, which prevents by a ſalutary Alarm the Diſaſters it would bring upon Men. 'Tis true, the Lightning does not in time warn the Man that is thunderſtruck; but it, at leaſt, warns the others to acknowledge the Hand of him, who both ſtrikes and ſpares.

How much ſoever we may be beholden to the Light, for the faithful Advices it gives us; yet let us not look upon the Fire as an Enemy. It is, on the contrary, an ineſtimable Gift. It never is offenſive in Man's Hands, but when ill-managed; and never hurts in God's Hands, but according to the wiſe Purpoſes of his Providence.

The Uſes of the Fire are too common not to be known. But it is not enough to know them in a looſe and confuſed manner. Let us trace the Fire in the Particularity of it's Operations. We ſhall be amazed to ſee the Variety of the Forms it puts on to ſerve us, and the Aſſociations it ſucceſſively makes to fulfil our Wants, very often without ſhewing itſelf.

The Action of the Fire is ſometimes help'd and accelerated, ſometimes reſtrain'd and bridled by the Air, the Water, the Oil, and the Salt.

Of all the Elements the Air is what the Fire can leaſt do without. The Air, 'tis true, does not give the Fire it's Being and Birth; but it helps it's Action, and makes it appear where it ſubſiſted unſeen. The Fire enters into the Compoſition of all terreſtrial Bodies. It can go through ſeveral of their Pores, and having enter'd them, may be tranſported with them from one Place to another. But it's not appearing in the Bodies it heats, or the Air wherein it dwells, proceeds from it's being there diſperſed in a ſort of Equilibrium, and in a Quantity, which makes it not ſufficiently active to be apprehended. It neither ſhines or is perceived therein, becauſe the Light is commiſſion'd to ſhew it us, only when it rages and is dangerous.

It becomes ſo, either by the increaſing of it's Quantity, or that of it's Velocity. It no ſooner is gather'd or quicken'd any where ſo as to dilate the ambient Air, but that Air contributes to the keeping it in. Firſt, Becauſe it confines that Fire in one Place, and hinders it from getting looſe ſo ſoon as it would without Air. We therefore ſee the flame of a Wax-candle diminiſhing in the Recipient of the Air-pump, in proportion as they exhauſt; and diſappearing and diſperſing itſelf very eaſily, on the Removal of the Air. Secondly, The Air nouriſhes the Fire or the Flame; becauſe being itſelf full of Particles of Oil, which are like ſo many Cells full of fiery Matter, it thus ſupplies the Fire with a Multitude of minute Rivulets of the ſame Element, which are drawn towards the Place where the Fire is collected and ſtrongly agitated; much as the Water of a River, or a Reſervoir, moves from all Sides towards the Place where the Equilibrum is diſturb'd. All flows ſucceſſively towards the Hole of the Flood-gate or of the Pump; and ſo much Water as goes out at a ſingle Place, ſo much Water is again ſupplied from a Thouſand. The Fire lighted, that is, collected in a certain Place, there maintains itſelf; becauſe ſo much Oil it has diſſipated, by ſcattering or waſting it on every ſide, and eſpecially above, ſo much new Oil does the circulating Air replace below. Therefore a Circulation of Air is really a Circulation of Fire. For this Reaſon it is, that you ſee the Flame of a Wax-candle always inclining towards the Fire on the Hearth, when it is any thing brisk. Wherefore, if you hold a lighted Wax-candle in a large Tube, wherein the Air freely circulates, it will continue burning there. But if you put it in a Tube, which it exactly fills, the Fire, which gets looſe at Top ſhall puſh away the Air. This, in the Reflux, will come and ſtrike againſt the Sides and the lower Part of the Tube, where finding the Paſſage ſhut, it no longer will ſupply the Flame with fewel, and this ſhall immediately go out. For a like Reaſon, the People, who work in the Mines, are very careful to place at the Entrance or Mouth very large Sails, which the Wind may be able to move, and which, by their Agitation, always drive freſh Air into the Bottom of the Mines. Their Lamps would go out, for want of that Aſſiſtance; becauſe the Fire quicken'd ſpreads preſently, and would ſoon be diſperſed, were it not replaced by ſome other, which is quicken'd in its turn by touching the Maſs of the Flame. Without this Renewal of the Air, the Workmen would not only loſe their Lights, but even their Lives, which conſiſt in a Fire, which the Air kindles, and which would let the Blood coagulate, were it not preſerved therein by freſh Air continually.

The Neceſſity of the Circulation of the Air for the maintaining of Fire, is very obvious wherever Fire is lighted; but chiefly when the Fat of the Soot happens to take Fire in the Funnel of the Chimney, and threatens the whole Neigbourhood with a Conflagration. If then the opening of the Chimney be not exceſſively large, as they were made formerly, you may be ſure to ſtop the Fire almoſt inſtantaneouſly, by ſtopping that Orifice with a Heap of Dung, or even by immediately ſpreading a wet Sheet before it, which, by the Plenitude of it's Pores, ſhall bar the Paſſage of the Air ready to go up the Hollow. They pretend, but I would not warrant it, that the firing of a Gun up the Chimney on fire, ſcatters the Air ſo violently below, that the Fire ſpreads and is diſperſed before the Air preſs'd and puſh'd away can return. You give the Fire, which breakes out in a Cellar, the Means of quitting the combuſtible Matter it devours, and of ſcattering along and through the Walls, by barring up the Entrance of the external Air into the Vents, with a good Quantity of Straw. They very often have put a ſudden Stop to a Fire, which had ſeized on a whole Room, by bringing in a Barrel of Water, in the Centre of which was ſuſpended a Box full of Gun powder. The Fire of a Match dipt in Brimſtone, which they convey to the Powder through the Water, by means of a long Tin-pipe, can no ſooner touch it, but the inflamed Powder violently drives both the Water and the ambient Air. The Air thus driven away and preſs'd, is not reſtored, nor does it return to its Place, till the Fire is diſperſed and out, for want of ſomething to contain it. Nay, the Water perhaps, in that Caſe, abſorbs a Part of it, which diveſt the reſt of all Power.

We are amazed on ſeeing a violent Fire, which conſumes whatever it meets with, and Hail-ſtones hard enough to remain unthaw'd for ſeveral Days together, ruſhing out of the ſame Cloud. So ſoon as the Fire of the Oils and the Sulphur, which is exhaled into the Air, begins to fire theſe Matters, by it's Acceleration between Clouds, which are puſh'd by contrary Winds, that Fire dilates the Air and ſcatters it afar off, with a moſt dreadful Fulmination. All the Space abandon'd by the Air remains likewiſe void of Fire; becauſe the Fire is never confined but by the Air. The Drops, which that Moment croſs the Space void of Fire, loſe all their own; they are frozen in an Inſtant, and follow the Thunder-clap very cloſe.

The Air maintains the Fire, not only by preſſing it enough to detain it a little in the ſame Place, or by perpetually ſupplying it by Circulation with a Courſe of ſubſidiary Fire, but alſo in accelerating the ſame Fire, by perpetual Shocks. For as the Air cannot feel the Acceleration of any Particle of Fire, without dilating; it is immediately repell'd by the ambient Air. Theſe Shocks, multiplied in Proportion to the Quantity of Air, claſh againſt the Fire, which thereby acquires a very great Increaſe of Velocity, wherein the Force of that Element conſiſts. For this Reaſon it is, that the ſame Air is not very long fit for the maintaining of Fire. For when it is dilated, it has no longer the ſame Activity, as when it was more confined; whence it happens, that a burning Fire-brand is ſooner put out in the great Light of the Sun, than in the Air of the Night, which is more fit to confine the Fire. For this Reaſon it is, that the cold Air makes the Fire ſo very briſk. It likely contains leſs Fire than in the Summer-time, but it unbends itſelf much more violently againſt the Fire it meets with, and increaſes the Activity thereof.

It is in order to procure that freſh Air, that we keep the Funnels of our Chimneys broad enough to contain on one Side the Column of Smoak, which the Fire cauſes to aſcend, and on the other a Column of Air, which deſcends. It is in order to be ſtill ſurer of the Return of the external Air, that we ſometimes lay into the Wall next to the Chimney a Pipe of Tin or of Iron-plate, that may by one End admit the external Air, and by the other convey it into the Earth, where it animates the Fire, and aſſiſts the Diſſipation of the Smoak. In Conſequence of the want of Air, we blow and agitate the Fire we have a mind to kindle. But that Agitation ought to be proportion'd to the Quantity of Fire, which was gather'd at firſt. If it is but ſmall, an exceſſive Agitation might extinguiſh inſtead of increaſing it. The Blaſt, which animates the Fire on the Hearth, would preſently put out the Flame of a Wax-candle. But how can the ſame Fan equally cool us, and light our Fire? The Fire does no more than this, *viz.* preſs the Air by driving it away, and makes the Fire flow out of it. For as the Inſinuation of the Fire into the Air dilates the latter, ſo likewiſe does the contracted Air cauſe a Part of the Fire, which it contains, to fly off. That Air therefore cannot be preſs'd upon us, without becoming ſomewhat cold, and without ſeeming to us charged with a leſs Quantity of Fire than before. But when the contracted Air, inſtead of affecting our Senſes, immediately claſhes with the Fire itſelf, which is gather'd in any Place, it increaſes the Motion of it. Now the Meaſure of the Quickneſs of the Fire is the Meaſure of its Strength. Whence it happens, that a Conflagration, which might have been ſtopp'd, had the Air been at reſt, in a Moment becomes ſuperior to all Efforts, if it be but ſeconded by a high Wind. The Quickneſs it then acquires becomes terrible. The Buildings, which ſtop it, by confining its Activity, and ſupplying it with new Fewel, increaſe its Fury. Far from leaving the Spectators the Liberty of affording Help, it ſcarce gives them Leave to get away. A Sheet of Fire, driven off by a ſudden Guſt of Wind, very often goes and ſurpriſes at very great Diſtances thoſe, whoſe Fears their Remoteneſs had baniſh'd.

You will not infer from hence, that the Wind ſhould always ſet the Air on fire. It, on the contrary, makes it always more or leſs cold, becauſe the Fire is no where collected therein, but equally diſperſed, and in a ſort of Equilibrium. The Wind does not blow towards any particular Point, but at large; and if a greater or leſs Quantity of Fire is gather'd between two contrary Winds, it is a little or a great Flaſh of Lightening, ſometimes a Flood of Fire, or the Thunder-bolt. You are alſo to remark,

mark, that there is no Wind but what cuts, and more or leſs retards the rapid Fall of the Light, and renders the Impreſſion of it leſs powerful on the Body of Fire diſperſed in the Air. All Winds in preſſing the Air towards us contract it, and make it ſeem colder to us. The northerly Winds, which blow from on high upon our Climate, preſs the Air down towards the Earth. The uppermoſt Strata preſs upon the lowermoſt, and make the Fire come out of them, juſt as the Water comes out of a ſqueezed Sponge. That Fire aſcends higher, and ſo the Air having leſs Fire neceſſarily contracts the Earth, and makes us feel a moſt ſevere Cold, when, being but lightly cloath'd, we let that Fire vaniſh, which our Blood ſtood in need of. The ſouthern and weſterly Winds, as they croſs over very ſpacious Seas before they arrive on our Coaſts, there drive before them, and every where diſperſe unconceivable Collections of watery Particles, which blunt and partly obſerve the Action both of the Light and Fire. The Winds that blow from the Land, or which come not to us before they have croſs'd over ſpacious Regions, are drier, and temper the ſultry Heats of the Summer, in proportion as their Blaſts preſs the Air by their Strength; or they render the Heats ſtifling and intolerable, when inſtead of breaking and blunting the Action of the Light, they, by their Repoſe, leave it the Liberty of darting on us all the Fire wherewith we are ſurrounded.

The Fire, which in Conjunction with the Air varies our Seaſons, and ſo powerfully influences either the Fruitfulneſs of the Earth, or the Health of Men, ſtill produces upon, and by means of, the Water, Effects full as important, though more conceal'd. To the Fire the Water is beholden for the Principle of its Action, ſince it owes its Fluidity thereto, which it always loſes on the vaniſhing of the Fire. It is very probable, that the Air is concern'd in it, and, together with the Fire, contributes to render the Water fluid; for you no ſooner put the Water into the Air-pump, and exhauſt the Air, but that, which is in the Water, being freed from the Preſſure of the external Air, gets looſe, and raiſes the Water, by dilating it into ſmall Bubbles; and if that Water is heated, the Air driven out of the Maſs of the Water by the Fire, makes the Water boil, as if it was on violent Fire. After that boiling, the Air, which remains in the Interſtices of the Water, may be quiet, and without any apparent Elaſticity, becauſe a Quantity of Water is eight hundred and fifty times as maſſy, and conſequently as heavy as a like Portion of Air.

Mr. Boyle's Explic.

We don't ſee, that the Water can be compreſs'd like the Air, ſo far as to take up a leſs Space than it ordinarily does. If you fill a Pewter-ball with Water, and beat it with great and repeated Blows, it will ſooner burſt than flatten and contract the Water, by the Diminution of its Bulk. But then again the Water, which is not compreſſible, is on the contrary greatly dilatable. It may, by means of the Fire, which more or leſs inſinuates itſelf into it, acquire an Expanſion, and of courſe an Elaſticity in a manner infinite. That it has in itſelf no Spring, I ſhall readily grant; but it receives from the Fire, which whirls in its Pores, a perpetual Tendency to dilate. That Elaſticity or Expanſion of the Water manifeſts itſelf, the Inſtant it is in the Air-pump, diſburthen'd of the Air, which preſs'd it.

The Water not only bubbles up in the Vacuum, and on the Fire; but there are alſo thouſands and thouſands of Particles of Water and of Air, which perpetually fly off from the heated Water, and wax round like Foot-balls. You know what they become in a more contracted and denſer Air than they themſelves are. We have formerly diſcourſed at large on the admirable Effects of their Evaporation, and of their being poiſed above. What we are here to remark, is, that the Fire is the Mover and Cauſe of both theſe. It is that Agent God employs uniformly to ſet at work that Pump, which raiſes the Water, and univerſally diſtributes it on the Outſide of the Earth, there to nouriſh the Animals and Plants, and from thence in the Bowels of the Earth, therein to convey the Salts, Oils, Sands, Mud, and metallic Particles, the various and continually renew'd Aſſemblages whereof are our Riches, and the great Supports of Mankind.

The Water and the Air, if left ſingly by themſelves, would be as it were inactive and void of Force; but being join'd with the Fire, they acquire Powers capable of ſhaking and overthrowing every thing.

The Globules of Smoke, which the Fire brings off from the Wood, and which are nothing but Air, Water, and rarified Oils; when they, in the Chimney, meet with the Laminæ of a Wheel made of Iron-plates, and horizontally placed on a Pivot, theſe Globules, I ſay, if conſtantly puſh'd by the Flame, which is kept beneath, have Strength enough to ſhake and puſh out of their Way, the Laminæ of Iron-plate that bar their Paſſage. The Smoke, which the Flame drives forward, ſtriking with redoubled Blows againſt all the Laminæ, which are inclined the ſame Way, there reſults from all theſe little and uniform Impulſes, a powerful Motion, which ſets the Wheel a-going. The Axis then, which paſſes through the Wheel, and takes in a Pinion of ſix Teeth, turns another Wheel of thirty-ſix Teeth. This ſecond Wheel, together with the Spit, which it makes ſubject to all its Motions by means of a Line, muſt needs make but one Revolution, whilſt the Smoke-wheel is performing ſix. The Machine, without any other Help but that of the Smoke puſh'd by the Flame, thus goes on turning very large Pieces of Meat, and roaſts them very regularly, without confining the Servants on that account to any troubleſome Care The going out of the Fire ſtops all; but when the Fire is out, the Meat on the Spit runs no risk of being burnt.

The Impulſion of that light Smoke, which borrows all its Force from the Shocks given by the Fire, helps us to gueſs what Jerks and Shakings very little Vapours may produce, when they are accumulated in the Mines or in the Air, and when the Fire, getting looſe within them, puſhes them rapidly againſt whatever is about them.

But if the Fire, always ready to be diſperſed, and too fine to act violently of itſelf, yet ſtrikes ſuch violent Blows, when it drives away and removes the Body of the Air and that of the Water, both much denſer than its own; its Action ſtill becomes incomparably more dreadful, when it joins the Force and Strokes of Salt to the Spring of the Air and the Water. The inflexible Particles of that Element are like ſo many Hammers, Wedges, and Levers, which it ſets at work. A very narrow Compaſs may contain thouſands of millions of Particles of Fire, of Air, of Water, and of Salt-petre. All theſe Principles are found in Gun-powder; nor is the Water excepted, ſince we find that alſo in the Reſolution thereof. The Particles of Fire and Air, which ſtrive rapidly to fill each of them five or ſix thouſand times more Room than before, and which are at reſt ſo long as they are ſeparately impriſon'd, no ſooner feel the Impreſſion of an external Fire, but they act all in concert; and by the Union and Concurrence of their Springs, by the immenſe Acceleration of their Velocities center'd in a very narrow Space, and finally, by the Multitude of little Surfaces of Water and Salts, which they dart, they make up an inconceivable Sum not to be meaſured, but of which we may judge by the throwing of a Bomb, or by the firing of a Bullet, which, in a few Seconds, is flung to the Diſtance of many hundreds of Fathoms.

The Fulminating Powder.

The Power of the Fire join'd to the Air and the Water, when theſe Elements are impriſon'd with a great Quantity of Salts, and animated by the Introduction of a new Fire, appears ſtill much more in the *Pulvis fulminans*. They pound three Parts of Salt petre, as, for Inſtance, three Ounces; they pound ſeparately two Ounces of Sulphur, and as much of Tartar, which is that Salt that ſticks to the Sides of the Veſſels wherein Wine has been kept. They blend theſe three Powders together; and having put this Compoſition in an Iron-ſpoon on the burning Coals, they retire and get out of the Way. The whole gradually melts in the Spoon; but the Fire of the Sulphur, and the new Fire, which join'd to it, being ſtopp'd and confined within, by the acid Salt of the Vitriol in the Sulphur, and by the little Waddings of the Salt-petre and the Tartar, are, by the conſtant Acceſſion of a new Fire, accelerated together with the Air and the Water of the Interſtices, to ſuch a Degree of Violence, that they at laſt break through the Arch of the Salts, and the Air, ſtruck thereby, reſounds like the Noiſe of a great Gun.

But without exactly knowing how the Fire communicates its force to the other Elements; and from the bare Knowledge of the Effects reſulting from ſuch or ſuch Mixtures; Men, by the Aſſiſtance of Fire, are able to boil, bake, roaſt, and dreſs their Victuals, and to facilitate the Converſion of them into their own Subſtance; to give their

Cloaths what Colour they pleaſe; to purify Metals by melting; to fetch the moſt ſtately Glaſſes out of a little Sand by Vitrification; to draw from miry Stones the Cement of Buildings, and a Principle of Fertility for the moſt barren Lands by Calcination; to re-unite with a fat Salt * the ſmalleſt metallic Particles, which the Separation hinder'd from being known again; to harden Copper, and make it yellow, by a Mixture of ſome certain Sands †; to render Metals ductile, ſoft and malleable by the Subtleneſs of the Oils with them mixt; to neal white Clay, of which, together with a little Sand, they make the Utenſils, which are moſt neceſſary to Mankind; to —— But in vain ſhould we here enter upon a more particular Enumeration of what we are able to ſoften, harden, divide, collect, faſten, glaze, and dye, by the Aſſiſtance of Fire. The Fire, as I may ſay, is the Inſtrument of all Arts, and ſupplies all our Wants.

It was in order to enable Man always to have at hand, and prudently to employ this ſo very precious Subſtance, that God was not ſatisfied with placing it only in the Air and the Water, but has alſo, and in a ſpecial manner, incloſed it in the Fat and the Oils. I know not what Oil is; but we all can ſee, that it is the convenient Magazine, which contains that ſo very dreadful and volatile Element. With its Aſſiſtance, we keep the Fire captive in ſpite of its Fury. We carry it wherever we pleaſe. We at our Will regulate the Quantity and Meaſure of it; and however ungovernable it may ſeem, yet it is always dependent on us. Beſides, God, by ſubmitting the Fire, has likewiſe ſubmitted the Light itſelf to us. Such are the magnificent Preſents wherewith he favour'd us, in placing oily Matters within our Reach. But Man, inſtead of diſcerning the Intentions of his Benefactor therein, very often admires only his own Dexterity, in the Uſe he knows how to make of them.

Here you have an Opportunity to aſk me, what can be the inexhauſtible Source, whence we receive again theſe Oils, which to us ſeem annihilated by Waſte? God, together with the Water, and the Salt, has, from the Beginning, pour'd into the Hollow of the Sea a Meaſure of Oil,

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* The Borax.

† The Lapis Calaminaris.

Oil, or of Bitumen, which he has proportion'd to the Wants of the whole Globe. The Fire and the Air inceſſantly raiſe from thence a certain Quantity of Water, of light Salts, and of minute Filaments of Oil. Thence the Rains, Fountains, Rivers, Vegetations, Nutritions, Savours, Odours, and all the Properties of Flowers, Fruits, Barks, Roots, and Woods. This Oil, unperceived in Rain-water, again collects in Plants its attenuated Particles. It acquires quite different Forms and Qualities, from its Union with the Water, the Earth, the ſeveral Salts, and the Principles of all Kinds. For Inſtance, when cloſed and wonderfully diverſified in the Duſts or Farinæ of Flowers, it conveys into the Seeds, as into ſo many Eggs a primitive Fire, which begins there to put in Motion the Organs, and the nice and delicate Nouriſhment it there finds already prepared. The Moiſture of the Waterings will continue to ſupply the Plant with Air, Oil, and all the other neceſſary Principles. Since a young Tree planted in an Earth, out of which the Fat has been carefully exracted by a Lixivium or Lye, and which was afterwards dried in an Oven, will grow and bear Flowers, Leaves, and Fruits; have Sapours and combuſtible Particles, without diminiſhing the Earth it was put in at firſt, one Ounce; though it has received nothing but what it drew from the Air, and the Humidity of the Waterings. This is a ſmall Inſtance of the Artifice, whereby God has incloſed the Fire in the oily Juices, as in ſo many Boxes or light Sponges, which the Winds tranſport, and the Water contains, in order to diſtribute every where the Matters, from which all our Tools, Victuals and Drink proceed. Theſe Oils, exhauſted and flatted, are impregnated in the Air with a new Fire and with the Rivers return to the very Sea, which collects them, ſupports a Part of them on its Surface, and expoſes them to the Action of the Air, to be raiſed a-new by a perpetual Circulation; ſo that if we have Reaſons to admire the Profuſion, with which God has furniſh'd our Reſervoirs, we have no leſs Motives of admiring that Oeconomy, which always employs the ſame Elements over-again, and makes them ſerve to ſupply the Wants of all Ages.

The Fire, which comes out of the Oils to make Plants vegetate, is ſtill more precious to us, on Account of its being the very Life of our Bodies. The Scripture points out to us, that the Life of the Animal is in its Blood. That Blood is no ſooner deſtitute of Heat, but it loſes its Fluidity and Life. The maintaining of the Fire and of the Motion of our Blood, in a Quantity and Degree whereof God alone knows the juſt Meaſure, makes the Duration of the animal Life; and it is in order to ſupply that Blood with Heat always new, and with the Principle of a perpetual Motion, that we inceſſantly breathe a new Air, from which the Fire is inſeparable. On the contrary, the Air we expire from our Lungs comes from them blunt, unelaſtic, and charged with the needleſs Humours it carries off from them. It is very eaſy to conceive, why Men are loſt in the Mines for want of freſh Air, and why we impair our Health, by living or ſleeping in Places too narrow and too cloſely ſhut. The Children of the poor Peaſants are fat and luſty, by only feeding on very brown Bread, and a few Milk-meats; while moſt of the Children of the wealthy, notwithſtanding the niceſt Diet, and in ſpite of Cares and Remedies, are tender, pale, and of a Conſtitution, which gives their Parents very frequent Alarms. The Reaſon of this Difference is very plain. The firſt always live in the open Air, and it is diſpenſed to the latter but ſparingly, and as if it were noxious. Inſtead of breathing that free and briſk Air, and full of Spring, in which God has put a juſt Meaſure of Fire, and of the Principles ſuited to the Neceſſities of our Blood; the Children of the Rich, always ſhut up and kept in the Shade, breathe only an Air that is uniform, without Spring, inſipid, and very often effœte and foul, in a narrow Alcove, by the perpetual Diſcharges of the Breath and Perſpiration. What can be the Purport of thoſe Shutters ſo well cloath'd, and of thoſe Curtains ſo exactly drawn acroſs each other? Sure the Parents aim at neither poiſoning or ſtifling theſe Children dearly beloved; but yet that is often the End of it.

When we conſider the Uſes of the Air, one might be apt to think that the Air is the Principle of our Life. We ſay the ſame of the Water, the Oil, and the Salt. When afterwards we come to the Conſideration of the Fire, we are apt to look upon it with Preference to other Elements, as their Mover, and as the true Source of Exiſtence. But none of them ſingly and in themſelves have any Virtue or Uſe. They have no Power one without another. One animates and enlivens them all; the other moderates and tempers them all. Take but away one ſingle Part of the Machine, and the whole will immediately be out of Order, and the Univerſe become of no Uſe to us. All remains dull and void of Action without the Fire. Even the Fire itſelf has but a blind Impetuoſity, if it be not govern'd. All theſe Pieces have then no Beauty, or any Force or Goodneſs, but what they receive from that Intelligence, which makes them take one in another, like the Wheels and Pinions of a Watch; and which makes them regulary play under the Direction of her Laws.

But how delightful is it for Man to ſee, that God has been thus willing to win his Heart, by conſtructing for his ſake, theſe magnificent Springs, and by permitting him to ſet them to work, when and in what Manner he thinks it agreeable to his Wants! Whatever is on Earth was placed within our Reach; and that Man might enjoy therein a real Sovereignty, God has granted him Leave, at his Will, to diſpoſe of the moſt active of Elements. By means of the Fire, he is Maſter of them all. The Fire, to which every Thing muſt yield, ſubmits every Thing to Man. For him it diſſolves Stones, liquifies Metals, and makes Iron pliant to all his Deſigns; Man, in ſhort, has the Thunderbolt in his Hands, without being an Uſurper; ſince he with Fire does whatever he pleaſes whether he be willing to gather or deſtroy, to maintain his invaded Rights, or only to procure himſelf an Exerciſe of Skill or of Amuſement. He throws down Ramparts, and breaks iron Gates. Animals fall under our Stroke at great Diſtances. Very often the whole Firmament ſparkles with Fires prepared by our Hands. The whole Atmoſphere is ſhaken. All Nature celebrates our Feaſts, and ſhares in our Rejoicings.

THE
THEORY
OF
FIRE.

DIALOGUE XII.

FROM the Review of the Services, which Heat does us, it is natural we ſhould come to the Examination of Heat itſelf. In what does it conſiſt? The whole we know of it is, that it is a Senſation more or leſs lively, more or leſs pleaſing or painful, whereby God affects us when Fire is preſent. But, what can Fire be in itſelf, and how does it act? If the Ground and firſt Principles of all Beings ſhun our Sight, who will undertake to dive into the Nature of Fire? It gets looſe, and pervades the Inſtruments, with which we endeavour to lay hold of it, and neither the Eye or Hand can bear its Approach. Let us diſcreetly go about this Inquiry. Let us behold it at a reaſonable Diſtance, aud be contented with the little we can know of it with Certainty. We ſhall afterwards paſs on to what is but conjectural; that the very Uncertainty of theſe our Suſpicions may convince us more and more, that

God has ſpread the darkeſt Clouds over his Works, though he has made us very clear-ſighted with regard to his Favours; and that the true Philoſophy does not ſo much conſiſt in a profound Learning, as in a lively Gratitude. What ſeems to me certain concerning the Fire, may be reduced to three or four different Heads. 1. Fire does not conſiſt, as modern Philoſophers commonly pretend, in a ſwift Motion of all kinds of Matter; but it is a real Body; it is an Element very different from all other Elements. 2. It is a Fluid. 3. It is a Fluid prodigiouſly elaſtic, and whoſe Spring may be infinitely augmented. It is a Body, which can neither be produced or deſtroy'd by any natural Cauſe.

Fire is a real Body.

As theſe Propoſitions are of great Concern, inſtead of endeavouring to anſwer them by abſtruſe Arguments, which always leave a very great Uncertainty behind them, we ſhall proceed here no otherwiſe than according to Experience. Fire is a real Body, quite different from other Bodies. We already have ſeen it every where diſtributed from one End of the Earth to the other, but more abundant in one Place, leſs active in another, and manifeſting its Preſence ſometimes in Proportion to its Quantity, ſometimes in Proportion to its Acceleration. All ſuch Bodies as may be equally agitated, ought to be equally combuſtible, were a great Motion and Fire but one and the ſame Thing. We nevertheleſs experience the contrary. The ſame Agitation of the Mill-ſtone, which grinds the Corn without producing the leaſt Sparkle, affords an immenſe Quantity of them, and will even ſet the Mill on Fire, when the upper Stone rubbing immediately upon the other, the inflexible Surfaces cruſh the Air intercepted between them, and having no Retreat, it accelerates the Fire reſiding in this Air ſo far as to ſet every Thing adjacent on Fire. Blackſmiths, Fullers, and many other Workmen know, that the Axis of their Engines, and the Wood that ſupports it, may be heated very ſoon; and to hinder it from taking Fire, they inceſſantly cool that Axis with a Stream of Water let fall thereon. This Water does not in the leaſt hinder the Swiftneſs of the Motion, and yet prevents the Fire.

A rapid Motion is then ſomething different from the Fire; it helps it; it accelerates it; but the Water, at the

Time that it lets the Swiftneſs of the Motion ſubſiſt entire, envelopes and abſorbs the Fire diſperſed in the Wood and the Air, which prevents the Inflammation of the other Matters. The continual freſh Air you drive ſwiftly over a hot Liquor, cools it only becauſe it contains leſs Fire than that Liquid, and robs it of a Part of its own. Fire is then a real Body, and not all kinds of Matters agitated.

Cold Fermentations.

Motion is ſo very different from Fire, that ſome ſalt Vapours, mix'd together and agitated, loſe a Part of the Fire, which they contain'd, or become palpably colder. We may convince ourſelves of this with a couple of Thermometers, one of which being dipt into the Liquor, by ſinking, ſhews, that the Fire gets looſe from it, whilſt the other offer'd at Top, and at the riſing of the Exhalation, mounts, and by its Dilatation evidences the Fire, which inſinuates into its Pores, and which the Motion of the Liquors has diſpell'd.

On the contrary, you will find other Matters wherein the Fire lodges in ſo great a Quantity, (though every one of its Particles be impriſon'd there) that the leaſt Motion is ſufficient to break the Chains of many, and ſet them at Liberty.

The Boulogne-ſtone.

For Inſtance, the Boulogne-ſtone, and ſome other Marcaſſites filed, cover'd over with their own Duſt, and then put into the Fire amongſt Coals well kindled, retain in their Pores ſo great a Quantity of Particles of Fire, that if the Marcaſſite feels no other Impreſſion than that of the Day-light, when it is taken out of the Cotton wherein it was kept, yet it ſeems ſparkling. That little internal Motion, which the Light communicates therein to the firſt Particles of Fire it meets with, awakes them from their Lethargy, or rather communicates to them an Acceleration that gives that Stone all the Brightneſs of a burning Coal.

The Phoſphorus:

All Phoſphorus's, I mean thoſe Bodies, which become luminous, being fill'd with the Matter of the Fire, in which they have been put at ſeveral Times, are to us a Proof of the ſame Truth. Different Fleſh, Blood, Hair, Shells, Horns, Meal, and an infinite Number of other Matters proceeding from Plants and Animals, but more particularly

Urines, are fit to make Phoſphorus. We eaſily penetrate them with a Fire ſometimes very briſk, and ſometimes ſo very weak, that it cauſes no ſenſible Heat at all, and very likely is detain'd by the Salt, which ſurrounds it. The Spirit of Nitre, and the Chalk, are able to produce a very fine Phoſphorus. * A little Allum and clarified Honey, are ſufficient to yield one of the moſt convenient. For without offending the Smell in the Operation, it may afterwards be preſerved five or ſix Months together in a Phial well cork'd; and a Grain of it thrown on Tinder will be enough to enable you to light a Candle. A Grain of *Engliſh* Phoſphorus, † which they preſerve in a Phial full of Water, to prevent the Diſſipation of the Fire, being put between two Papers, if you force your Nail over it to cruſh it, your Papers will immediately take Fire. Take a ſmall Piece of the ſame Phoſphorus, and write with it whatever you pleaſe on a white Paper, the Letters will not be ſeen; at moſt a little Smoak will riſe therefrom, and give you the ſlighteſt Glimpſe of them. But the ſingle Shock of the ſmall Particles of Air, which ſtrike againſt the Fire contain'd in thoſe light Strokes, is ſufficient to enliven it ſo far as to be extremely bright. There is no need of a Candle to read a Letter written that way. It carries its Light with it; but we muſt be in the Dark to make uſe of it. There all the Characters will appear luminous, and be the more ſenſible, in Proportion as the Obſcurity is greater, and as you will ſee nothing but them. This magnificent Phoſphorus, the Compoſition of which is no Secret, and which till now was but a Curioſity, might be render'd of Uſe. We might employ it to explain our Minds from one Ship to another while 'tis dark, or to give Notice of the Wants of a beſieged Place to thoſe, with whom we ſhould have agreed about the Signification of ſome certain Characters. But the Uſe of the Phoſphorus is not here the Object of our Inquiries. It is enough for us to obſerve, that the Manner, in which it is compoſed, aims at nothing but to drench, or, as it were, to ſatiate it with the Matter of the Fire; and that the Care we take to preſerve it in Water is

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* The Hiſtory of the Academy of Sciences, 1711, 1714. 1730, &c.

† Invented by Mr. Kunkel, Chymiſt to the Elector of Saxony.

is grounded on this, *viz.* becauſe the Water efficaciouſly detains the Salt, which is itſelf the ſtrongeſt Priſon of the Fire.

It is becauſe the Fire is a Body, and an extremely fine and ſubtle Body too, that it eaſily gets looſe through the Pores of a hard Body, and is ſtop'd by the ſmall Surfaces of a Body that bears ſome Proportion with regard to its Fineneſs and Tenuity. A Bottle of hot Water ſooner grows cold in a marble Veſſel than in the open Air, and its Fire, which flows off into the Marble and the Air, is very long preſerved when wrapt up in Stuffs or in Wool; becauſe the Strata of Air, which reſiſt it, are then as much multiplied as the Fibres of the Wool, which ſtop that Air, and the Reſiſtances are multiplied as much as the Surfaces. The Fire alone would eaſily go through each Thread; but it is detain'd or entangled a longer Time in the Air, with regard to which theſe Threads are ſo many impenetrable Textures.

The Fire is ſo truly a real Body, that it dilates all the Bodies it enters into. An Iron-bar made red-hot becomes a little longer and broader than before. The Iron-gage or Meaſure, which ſerves as the Standard in ſome Courts, or in public Matters, does not always agree with itſelf; it lengthens half a Line, or even more in Summer-time, and ſhortens in the ſevereſt Colds. The Pendulum of Clocks lengthens a ſmall Matter towards the Æquator; which concurring with the ſlight Diminution of the Weight in thoſe Places, obliges the Inhabitants thereo to ſhorten the Pendulum; that it may beat true, and not too ſlow. Watchmakers and other Workmen very often obſerve, that a Piece of Metal loſes its juſt Meaſure, and lengthens a little in great Heats. A Pivot too exact, and which too cloſely fills the Cavity it turns in, may, when it grows hot, ſo dilate, as to retard the Watch by the Increaſe of the Friction.

What, beſides the Inſinuation of the Matter of Fire could widen the Bottle of a Thermometer, and ſwell the Liquor therein? The Approach of a Wax-candle, you Breath, or your Hand, conveys the Fire which flow from thence into the Pores of the Bottle, which contain the Spirit of Wine. You firſt ſee the Liqour contrac and ſink; becauſe the Belly of the Bottle, ſomewha

dilate

dilated, gives the Liquor more Room; but the Fire immediately paſſing into the Liquor itſelf, makes it riſe very ſenſibly; becauſe it increaſes the Bulk thereof. Here is an Inſtance ſtill more convincing.

* If a Plate of Steel has on the one Side of one of its Extremities ſmall Teeth like a Saw, and thoſe Teeth take into a Pinion that ſets ſeveral Wheels a going, the latter of which ſupports an Index, when you preſent the Flame of two Wax-candles to that Plate, it will ſo effectually ſtretch out and lengthen by the Inſinuation of the Matter of the Fire, that it will ſet ſome of its ſmall Teeth a-going, and by a neceſſary Conſequence will make the Pinion and the Hand to turn; and if there be ſeveral Wheels that take into other Pinions, the Motion of the laſt ſhall be extremely ſenſible. When the Lamina cools by the Efflux of the Fire, it will neceſſarily ſhorten, and make both the Pinion and the Hand play the contrary way. To theſe palpable Proofs, which demonſtrate the Preſence of a real Body, let us add thoſe, which are fetch'd from its Properties. The more we ſhall know of its Properties, which characterize it, the leſs ſhall we be tempted to miſtake it for the bare Motion of the Part of any Body whatever.

Fire is a Fluid.

Fire is a Fluid, and its Tendency towards ſpreading every where and every way, is an Effect of its Fluidity. It is becauſe Fire is a very penetrating Fluid, that it always endeavours to be every where on a level, or in a State of Equilibrium. A hot Body, that is, a Body full of the fiery Matter, being applied to cold Bodies, ſuch as Steel or Marble, communicates its Fire to them. A hot Marble being brought near another leſs hot, we by Degrees experience them to be of a perfectly equal Heat; but as much Heat as the ſecond Marble acquires by that Contact, ſo much Heat does the firſt loſe. The Fire, by inſinuating itſelf into Bodies, does then endeavour to ſpread therein, in an equal Quantity on all Sides, and thereby manifeſts its Fluidity to us. We may eaſily obſerve this in the Care we take to pour, from one Veſſel into another, Liquors we have a mind to cool, by the Efflux of the Fire

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* An Experiment of Dr. Deſaguilers, F. R. S. of London.

into the Subſtance of a Veſſel leſs warm than that we empty. It is ſtill more obvious in the tempering of hot Metals. If we dip into cold Water the End of an Iron-bar made red hot in the Fire, Part of that Fire flows into the Water, which contains a leſs Quantity of it than the Iron. It dilates the Water, and makes it bubble and boil. The Out-ſides of the Iron, left by the Fire, contract by the violent Shocks of the raging Water, which compreſs them, and become harder than they were before. So that the Fire, which remains within the Thickneſs of the Bar, has no longer the ſame Liberty to ſpread and flow toward the End and the Sides; becauſe they are both contracted and harden'd; but above all, becauſe it finds too many Obſtacles in the Water violently heated, and full of another Fire, which repels it. The Fire then finding leſs Reſiſtance in the Maſs and Length of the Bar, than in the Out-ſides of the temper'd End; it ſoon recedes from it; it creeps to the oppoſite Extremity, and the Bar, hot as it was in the Hand of the Workman, when he made the End of it red hot, ceaſes to burn, the Moment it is temper'd.

When, I ſay, that the Fire penetrates Bodies after the manner of Fluids, and that it ſpreads in an Equilibrium, I mean, that it begins by doing there at leaſt what Water does when it enters the Sand. It does not penetrate the Maſſes of that Sand, but it lodges itſelf between the Interſtices, which ſeparate them; and when it is either abundant or agitated, it may poſſibly raiſe the Grains of Sand, and carry them with it a good Way, as though they alſo were become fluid. Thus it is, that the common and moderate Fire heats all ſuch ſolid Bodies as Iron, Wood, and Stone are; it enters them without diſplacing the little Maſſes, between which it enters; and when it ruſhes into them with a greater Force, and in greater Plenty, it diſſipates, it melts, it calcines; which in the main is ſtill no more than diſuniting and carrying off.

The Fire has the ſame Effect on ſuch Bodies as are, from the fineneſs or roundneſs of their Particles, apt to be diſunited, and with it form a more or leſs denſe Fluid. By its Fluidity it diſſolves Salt, melts the Ice, ſoftens the Wax, makes the Oil to flow, and hinders the Liquors from hardening. It communicates to them its own Fluidity,

dity, By keeping them in a State of Diſunion, and by ſpreading, not indeed in the very Heart, but in the Interſtices of their Moleculæ or little Maſſes. When the Fire has Activity enough to get from the Interſtices into the very Moleculæ of ſome Fluids, as of Wax, Tallow, Oil, Spirit of Wine, or melted Brimſtone; there it finds, as in ſo many Cells or ſmall Purſes, a hidden Fire, which they had the Power to retain. That ſecret Fire, joining with the external, acquires an extreme Violence. They are two Fires, which unite their Force; and then it is, that the Inflammation becomes conſiderable.

How Liquors are cool'd.

The ſame Fluidity of the Fire affords us an eaſy Means to account, how a Liquor ſo full of Fire as Wine is, may nevertheleſs be cool'd to ſuch a Degree, as to appear to us as cold as Ice. The ſecret Fire, which together with ſome other Principles, makes up the Quality and Strength of the Liquor, is therein temper'd and ſtrictly bound or reſtrain'd by theſe Principles. It is as it were ſhut up and incloſed in Caſes, which are able to bridle or contain it in Spite of its Activity. This eſſential Fire is not in the Interſtices of the Wine, but in the Heart itſelf of the little Maſſes that compoſe it. And when the Liquor ſeems cool, notwithſtanding that internal Fire, it is becauſe the Air of the Cellar, containing leſs Fire than the outward Air, ſheds a leſs Quantity of it through the Pores of the Glaſs in the Interſtices of the Liquor. If the ſame Wine afterwards grows hot in the Air, it is becauſe the Fire of the Air is a Fluid, which has a Tendency to enter into whatever is offer'd to it. And that heated Bottle ſhall cool again in cold Water; becauſe the Fluid of the Fire, which is in the Interſtices of the little Maſſes of the Wine, will not fail to ſpread, if poſſible, out of the Bottle, and to get into the Water, which is preſented to it. Now that Quantity of Fire, which is freely diſtributed in ſo great a Bulk of Water, came from the Bottle. Whereſore the Liquor muſt then be much cooler than our Air, and our Blood. That Drink ſhall then, when it enters the Body, be very fit to be fill'd with the too abundant Fire, which troubles and inflames the Blood. It cauſes therein a Contraction, which, if moderate, cannot but be wholeſome. Were it ceſſive, it would rob the Blood of the greateſt Part of the Fire, which makes it fluid; it would coagulate it, and choak up the Veſſels.

When we have our Hand very cold, and apply it to the Heart, the latter does then experience a Cold, which contracts it; becauſe the Matter of the Fire does that Moment abundantly flow from our Blood, and ſpreads in the Hand more eaſily than in our Cloaths, which contain and ſtop a great Quantity of Air and Fire between their Threads; whereas the Hand, void of that Element, opens all its Pores thereto.

The Ice likewiſe is very fit to cool Wine, becauſe it contains almoſt no Fire at all. I ſay, almoſt none; for it is not wholly deſtitute of it, ſince it evaporates, and in time leſſens its Weight; which would not happen, did not the Fire carry off a few Particles of Water from it. Therefore the Ice cools the Wine, not indeed by communicating to it Cold, which is nothing, but by robbing it of a great Part of the Fire, which lodged in the Pores of the Wine, and which the Water does then receive into its own. It is on the Fluidity and Transfuſion of the Fire, that the Salubrity of cool Oyſters, of Radiſhes, Sallads and Baths is founded. The Water of the Bath, and theſe Foods, as they contain but very little Fire, the more eagerly abſorb that, which devoures us; whence proceeds that ſudden ſedateneſs of the Blood, which we experience almoſt equally from the Uſe of freſh Oyſters, and that of Bathing. As Phyſics and Nature concur to inform us of the Neceſſity of cooling our ordinary Drinks, in order to abſorb a Part of the Fire, which heats our Blood; inſtead of Ice, which is not always to be found, or the Uſe of which agrees not with all Stomachs, and which is deſtroy'd by the very Uſe we make of it, we may employ ſeveral Sorts, which being thrown into the cooling Ciſtern, make the Water almoſt as cold as Ice itſelf, by compreſſing between their Laminæ what Fire they find in the Water, and thus occaſioning the Efflux of the Fire out of the Bottle. We may have the ſame Service from Sea Salt, and better ſtill from the Sal Ammoniac. As both theſe Salts may be cryſtalized at the Bottom of the Veſſel, by the Evaporation of the Water, their Services may be repeated ſeveral Times; ſo that the Expence is not greater than that of the Ice. The Salt, which is extracted from the Sea-weed, being almoſt of the Nature of the marine Salt, and extremely cheap, may ſupply the Place of all the reſt. It is a common Saying, that extinguiſh'd Coals, or a few Bits of Brimſtone dipt into the Water, will cool it. They ſay ſo indeed; but Experience ſhews me the contrary. The Coals taken out of a Cellar might perhaps have ſome Effect that way; but that is a verry ſorry Shift.

No doubt you would be glad to conceive, how the Diſſolution of Salt can render a Liquor colder. The moſt ſatisfactory Account I can give you upon that Head is, that the Water having no other Action and Fluidity but what it receives from the Fire ſpreading in its Pores; ſo ſoon as that Action ſhall begin to communicate itſelf to the Salts, and reduce them alſo into Liquor, the Water neceſſarily loſes by their Diviſion. It loſes the more, becauſe it is the Property of Salt to impriſon the Fire cloſely, and, as it were, to chain it up; and the Ground of this is, that the little Laminæ of the Salt are more impenetrable by the Fire than any other Element. The Loſs, which the Water ſuffers of that Fire, which is diſperſed and captivated between the Laminæ of the Salt, is ſo great, that it oftentimes is follow'd by a perfect Congelation. Nay, a Handful of Salt and Snow mix'd together, and applied on the Out-ſide of the Bottle, is ſufficient to rob the Water it contains of all its Fire, and to impriſon it ſo far as to make the Water of the Bottle freeze, even in the Middle of the Summer.

The Origin of the Signs of Coolneſs.

The cooling of Liquors leads us naturally enough to the looking into the Fluidity of the Fire for an Anſwer that may ſatisfy to the Queſtion you have ſo often heard made at Table. What is that Cloud, which cold Wine never fails to ſpread on the Glaſs ſo ſoon as it is pour'd into it, and which brings upon the Servants Reproaches, uſeful perhaps, but oftentimes undeſerved? It is the Cold of the Liquor, ſay they, which thickens the ambient Air, and turns it into Water. But how is that conceivable? If Cold is nothing, it can produce nothing. Beſides the Air is conſtantly Air;

and all judicious Chymiſts agree, that Water never changes its Nature.

The Fire alone operates every Thing here, either by its Preſence or Retreat. The Wine drawn out of a cool Cellar evidently contains much leſs Fire than the external Air heated by the Sun. The Fire whereof the Air is full, by an Effect of its Fluidity, ſtrives to get Admiſſion into every Place. It then enters through the Pores of the Bottle, and ſpreads in the Liquor, till it is there in a perfect Equilibrium, or in the ſame Quantity as it is in the Air. But we ſaw in another Place, that the Air is at any time, and eſpecially in the Summer, full of evaporated and attenuated Particles of Water, which the Fire ſuſtains there, and which cannot be admitted where the Fire is. So ſoon as the Fire inſinuates itſelf into the Bottle, the Air, and eſpecially the Water, which the Activity of the Fire ſuſtain'd, are abandon'd by it at the Entrance of the Paſſages; where they immediately thicken as a Fog, and afterwards gather into a Maſs, which gutters down in ſmall Torrents on the Sides of the Bottle. The ſame Thing happens on the Out-ſide of the Glaſs, into which a cool Liquor is ſuddenly pour'd. Let it be either Wine or Water, the Effect is equally the ſame; becauſe it proceeds, not indeed from any Fire eſſential to the Liquor, or from any Quality inherent therein, but from the Equilibrium of the external Fire, which ſpreads wherever it finds a free Place, which goes backwards and forwards into the Pores of the Glaſs, and of the Liquors, and which, by inſinuating itſelf from the Air into theſe Veſſels, lets thoſe Particles of Water, which it volatilized, fall on the Out-ſides of the Glaſs. If you empty your Glaſs of the cool Liquor, then a cloud of Moiſture is form'd within, as well as on the Out-ſide of the Glaſs; becauſe all, or nearly all, the Fire, that was in the Subſtance of the Glaſs, having flown into the cool Liquor, that Liquor is no ſooner removed, but the Fire of the Air enters into the Thickneſs of the Glaſs on both Sides at once. But ſo ſoon as the Fire of the Air ſhall have put itſelf in an Equilibrium, both in the Air and the Bottle, or the Glaſs, you will no longer ſee any Thing of this kind. When the Fire ceaſes to enter into them, there is no longer any Fire, which abandons the aerial Water, which of Courſe ceaſes together.

ther. Let us trace this Mechaniſm, and the natural Effects of the Fluidity of the Fire; in order, from this Inquiry, to find out the Solution of ſeveral Queſtions wanting Explication.

The Origin of the Moiſtneſs of Marbles, Pavements, &c.

It is commonly ſaid, that the Marble, the Chalk, and ſquare *Dutch* Tiles attract the Moiſture. Having here Recourſe to Attraction, would be diſcourſing in the learned Strain on what we ſhould not underſtand. Theſe Matters do not attract, but only ſtop the Water. They yield a free Paſſage to the Fire, which they refuſe to the Water by it divided. Whenever there is in the Air of an Apartment more Fire than in the Walls, that Fire endeavours to ſpread every where in an equal Quantity. Now, it cannot enter the narrow Pores of the Marble, the Chalk and glazed Earth, without leaving a thouſand and a thouſand Particles of Water at the Entrance of the Paſſages, which are too ſmall to admit them. This Water will gather there ſo far, as to form a ſenſible Coat of Moiſture. The Fire penetrates through, and gets away; but the Moiſture remains. It afterwards evaporates from off the Walls. Another Coat ſucceeds it, and takes the ſame Courſe. Theſe Vapours removing from the Walls, ſwim in the Apartment, juſt as we ſee them roll in the Air-pump, after the Air, which kept them rarified, has been exhauſted. They make the Air thick; they even may render it pernicious to the Health, when they are over-abundant; and ſtill more ſo, when they mix it with the Saltpetre, which they carry off with them from the Foot of the Walls, whither it is ſent and extracted from the Urines, which penetrate the Earth; which never happens in an Apartment built on a Stone-arch. Tapeſtry hangings, on the contrary, hair Stuffs, Fleeces, Skins dreſs'd with their Hair on, and even the wood of Wainſcoats, of inlaid or of plain Floors, as they contain in their Fibres, and in their wider Pores, a very great Quantity of Air, the Fire, which is in Equilibrio in the Air of the Room, and in that of thoſe Fibres, cannot flow thereinto with the ſame Liberty, and meets in that Multitude of ſmall Particles of Air and Surfaces a greater Number of Obſtacles to its Paſſage, than in the narrow Pores of the Marble. Among Woods, the moſt compact, as Box, always is colder than the moſt porous, as Cork, which retains a great deal of Air and Fire in its Pores.

The Origin of the Hoar-froſt.

The ſame Fluidity of the Fire moſt ſenſibly ſhews itſelf, in very cold Weather, on the Glaſs-windows of our Apartments. The Fire incloſed in the Air of a Room, neceſſarily ſpreads on every Side, if it be fluid. It muſt needs endeavour to get looſe, and plant itſelf wherever there is the leaſt Quantity of the ſame Element, and it will make no Effort to flow into an Air already as hot as that it is poſſeſs'd of. It will therefore be ſtopt by the Wood, and more ſo ſtill by the Tapeſtry-hangings, which contain a great deal of Air. On the contrary, it will flow off through the moſt compact Texture of the Glaſs-windows, which contain neither Fire or any Water. It will diſperſe in the colder Maſs of the external Air, till there is an Equilibrium both in the external Air, and that of the Room. The Fire, which goes out through the Window, leaves within, and at the Entrance of the Pores, the Particles of Water and Air, to which it was united. Theſe form a Cloud, which grows denſer in Proportion as the Fire goes out. At laſt the Quantity of Fire, which by little and little flows into the cold Air without, is ſo great, and that, which remains in the Maſs of Air within the Room, becomes ſo very ſmall, that it can no longer keep the Particles of Water, which are condenſed on the Glaſs-window, in a State of Fluidity. That Water muſt needs then freeze; and really all the Particles of them fall one on the other by ſmall Parcels, or by Filaments much of the Nature of Snow, forming at random ſome ſeeming Foliages, according as their Weight, or the Impreſſion of the Air, has hurried them to the Right or Left, and they are drawn near to each other in the Congelation. This is what we call a Hoar-froſt or Ryme, which, as you ſee, muſt be, and in Reality is, form'd on the Side of the Glaſs-windows next the Apartment. But ſo ſoon as the external Air ſhall acquire a greater Heat than within the Houſe, by endeavouring to ſpread from without in the Room, then the Moiſture will appear on the Glaſs-windows without; this we experience in every Thaw. In Conſequence of the ſame Fluidity of the Fire, when the Air, which has been a long while cold in large Halls, ſhall begin to become warm again, and the Fire penetrate in greater Quantity the Columns of Stone, the Marble, and the Pictures; then the Moiſture ſhall hang on the Out-ſide of them, and flow down them in Streams.

From the ſame Cauſe proceeds the Thickening of our Breath, ſo far as to be ſenſible when the Weather becomes cold and cloudy. The Efflux of the Fire from our Breath into the external Air, lets the moiſt Particles of it fall one upon another; and they are the more ſenſible, when they meet in the Air with ſome others, which are an Obſtacle to them.

Diſtill'd Waters.

The Thickening of our Breath on a Marble, a Glaſs, or any other very compact Body; the Re-union, which is made of the Vapours of boiling Water under the Cover that ſtops them; the Condenſation of the Fumes of an Alembic, when they adhere to the Top, and contract in a Pipe ſurrounded with cold Water; the gathering of the Dew on a Glaſs or a Marble, rather than on a Cork or on Fir, are again ſo many Operations wholly owing to the Fluidity of the Fire, and the Coarſeneſs of the Matters it ſuſtain'd. Theſe evaporated Matters would meet with a Reſiſtance, and be obliged to undergo a Conflict, did they meet with any Air or Fire lodged in the Pores of the Cork, and ſtill more ſo, if they ſhould meet with a Cover red hot, and full of another Fire. They would by repell'd thereby; but the Fire getting quietly looſe through the ſmalleſt Pores of a cold Marble, of a Glaſs, of a Piece of Slate, or of Glaſs deſtitute of Heat and Air, there quits the Company of the watery Particles, which prove too groſs for ſo narrow a Paſſage. Theſe Particles ſtick thereto, without being able to proceed any farther. The Body that ſtops them is properly a very fine Sieve, which gives Paſſage only to the Fire. Every Body knows that cold Meat hardens, when you warm it again in Water; and that, on the contrary, you may warm it without making it either hard or inſipid, by putting it into an earthen Pan well cover'd, and placed in an earthen or caſt-iron Pot, in which Water is actually boiling, call'd the vaporous Bath. The Fire inceſſantly raiſes from the boiling Liquor bubbles of Air and Water, which ſpread all round the earthen Pan. The Fire, which penetrates the Pores of it, gently warms the Meat already prepared; but the Water it quits condenſes under the earthen Pan, and thence gutters down in large Drops.

Let us proceed, running over the other Experiments, to prove the Fluidity of the Fire, and its Tendency towards putting itſelf to a Level, and in Equilibrio, wherever it can get Admittance. It is in order to ſhelter us from the Efforts of the Fire reſiding in the external Air, and which is always ready to ſpread every where, that we in Summer-time oppoſe its Paſſage by Curtains and Window-ſhutters. What we get by this is not to free ourſelves of it entirely, but to experience much leſs of it, and to breathe an Air colder than are the Humours of our Body.

* It is becauſe the Fire, notwithſtanding all our Caution, gets into our Apartments, that it comes and inſinuates itſelf to the very Bottom of our Cellars. Though they ſeem to us then to be very cool, they in Reality contain more Fire than they did in the Winter, when they appear'd warm to us; ſince the Thermometer was then lower therein than it is in the Summer. And theſe Appearances, which ſeem contrary to Truth, convince us, if we do but conſider, that God has regulated the Order of our Senſations, and the Notice he gives us of what paſſes without, not on the State of Things themſelves, but on the Importance or Concern they may be of to us, and purely as they relate to ourſelves. We then in the Summer perceive the Air of the Cellar, or of a Marble-Hall, very cool, not that it then is void of Fire, or that it contains leſs of it than in Winter; but becauſe that Fire being much weaker than that of the external Air, which ſcorches us, we are inform'd by the agreeable Coolneſs that is perceived in low Places, or in the Liquors drawn out of them, that we have found a ſure Means of freeing ourſelves of a great Part of that exceſſive Fire, which dilates and diſorders the Humours of our Body. And the Air of the Cellar, on the contrary, ſeems to us hot in Winter, not that it then contains as much Fire as in

Summer-

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* Whether Cellars and Vaults are indeed warm in Winter, and cold in Summer.

Summer-time, but becauſe it contains a greater Quantity of it than that, which actually floats in the external Air, which affects our Body, and may occaſion too great a Loſs. This variety of appearances is perfectly like that which we experience, when having one hand very cold, and the other very hot, we dip them both into luke-warm Water. The Water ſhall ſeem very warm to the cold hand, into which it inſinuates it's Fire; and very cold, on the contrary, to the warm hand, which it robs of it's own.

The Elaſticity of the Fire.

Having proved the Fluidity of the Fire, we have by that proved it's Elaſticity, or it's natural Diſpoſition to ſpreading, and every way puſhing againſt what ſurrounds it; with this difference between it and the other Fluids, that Fluidity and Elaſticity are inherent and proper to it, whereas others perhaps receive that activity from it. A Croud of other Proofs, which we daily have under our Eyes, more than ſufficiently convince us, that the Fire inceſſantly ſtrives to make itſelf a Paſſage every where, to dilate on all ſides, to ſpread all round, to proceed, to penetrate, to diſſipate. Is there any thing that it cannot go through or diſſolve? But this ſo powerful Elaſticity does not always act in the ſame manner. There are even Caſes, in which it is no longer ſenſible, even in a very great Fire. We very often ſee the Fire rolling on itſelf, and without fewel in luted Veſſels, quietly getting looſe out of them, and to appearance making no manner of Effort to break them. If the Strength is always the ſame, whence can this Diverſity proceed?

There are in Nature but three truly fluid Bodies known, and which, by their perpetual Activity, are the Principles of all Motion. I mean the Light, the Fire, and the Air. The Light is an univerſal Fluid, which extends to the very Stars; our Fire and our Air are two Fluids attach'd to the Earth for the ſervice of Man, and ſpread round his Habitation. The Light is of ſuch prodigious fineneſs, that it pervades the Textures of all Bodies, and influences them only by help of the Fire, with which it is in an exact proportion. It puſhes the Fire, and is thereby reciprocally repell'd. It renders the Fire more active, by communicating it's Motion thereto; and the

Fire, troubled or forced out of its Equilibrium, reciprocally acts upon the Light, and makes it ſhine. But the Body of the Fire, though maſſier than the Light, is yet too fine to be able of itſelf to diſplace the Maſſes of terreſtrial Bodies. It croſſes, without diſuniting them. It gradually flows from, without breaking them. It every where finds Paſſages free enough to get looſe, without making any fracture. But by the Shape of it's Particles it keeps an exact Medium between the Light and the Air. And as the Air is a maſſier fluid than the Fire, it's Union with the Air makes it already more capable of acting upon the Bodies it would only have grazed upon, or have penetrated without Oppoſition. The Fire, in itſelf full of Activity, borrows a double Acceleration, and conſequently a double Force, both from the Impulſion of the Light, and the Spring of the Air let looſe againſt it.

Fire borrows many powerful Helps beſides from the other Fluids, ſuch as Oil, Mercury, Salt, and Water. But it is aſſiſted by them in a very different Manner. Theſe Elements have only borrow'd Fluidity. They are elaſtic, or inclined to dilate only in proportion to the Quantity of Fire they receive into their Pores; ſince they coagluate or freeze by the Efflux of the Fire. When they are added to the Fire, they properly add nothing to it's Quickneſs; but it is not to be imagined, how much they contribute to render it's Action terrible, and full of force. The Oil ſupplies the Fire it is thrown into with another very plentiful Fire, and a Multitude of Bubbles of Air it retain'd captive in it's little Maſſes. It is an eaſy Matter to obſerve the Conſequences of it. Oil is the true Fewel of Fire. Mercury, Salt, and Water, may impriſon and ſurround the Fire, and render it of no force; but if that Fire comes to increaſe it's Quantity and Celerity, it is then the more dreadful, becauſe it acts in Concert with thoſe Elements, and drives before it Maſſes capable of barring it's Paſſage, and which will help it to overthrow every thing; whereas, without the Oppoſition of their Surfaces, the Fire would be diſperſed through a greater Space, or flow out through a greater Number of Pores, and thus remain without Effect. It is the Proportion of the elementary Parts, which makes the Variety of the Effects of the ſame Power. Throw the ſmalleſt Flint into a great Fire, the Fire and Air, which encompaſs the Surface of it, have not Power enough to throw you that Maſs back. Do but pour Water into a great Fire; the Proportion between the little Maſſes of Water and thoſe of the Air animated by the Fire is ſuch, that the Water, in itſelf without Activity and Reſiſtance, ſhall on a ſudden be ſent back and repell'd with a prodigious force and degree of Expanſion. It hurries away with it Aſhes, Coals, Shards of Pots, Bricks, Stones, and whatever it meets with, and oftentimes produces very ſad Accidents in Kitchens.

The Fire and the Air, which exhale from Hay or from Sheafs of Corn newly put together in a Rick, are diſſipated without any Danger, if the whole be well dried. But if the Heap be moiſt, the Fire and the Air ſtop'd by that Moiſture, heat it ſo far as to penetrate and rot, and even ſometimes ſo far as to fire the Rick. The Farmer may prevent this Miſchief. When rainy Seaſons force him to houſe his Harveſt without an Opportunity of drying it, he places in the Middle of the Rick two or three large Faggots of Thorns, and by that Means leaves a large Space, to which the Fire and Exhalations coming from all ſides, dilate, and thus loſe all their Force and Activity.

The Æolipyle.

We ſhall find the Proofs of a like Mechaniſm in the Æolipyle. It is a ſmall Veſſel of Braſs of the Form of a Pear, having towards it's Point a ſmall crooked Pipe, with an Orifice of about the twentieth Part of a Line. When this Veſſel is put on a very quick Fire, the Fire ſhall dilate the Air within. It ſhall go backwards and forwards through the Pores of the Pear, without any ſenſible Alteration; becauſe the Air it drives away finds a Vent through the Orifice of the Pipe. If that Pear, being red hot, be dip'd into the Water, the dilated Air therein contracts on the Approach of the Water. The Veſſel by degrees is fill'd with Water and Air by pretty near equal Portions. Now, again, put the Æolipyle on the Coals, with the ſmall End of it dipping towards the Fire, and the Orifice of the Gullet turn'd upwards, which by this Means the Water fills without flowing out. So ſoon as the

the Fire is clear, that Element, which ſeem'd not to act on the Inſide of the Pear when it was without Water, and nothing to confine it, begins by dilating the Air there. The Air unbends all it's Springs againſt the Water, which ſurrounds it. This, though by Nature void of Activity, being ſtrongly puſh'd every way, and at the ſame time confined by the ſides of the Veſſel, finds no other Iſſue but the ſmall Vent of the Gullet, towards which, all the fury of the Fire and the Air, and of Courſe that of the Water, turns and centers. The Water guſhes out of it, notwithſtanding the Smallneſs of the Vent, and the Reſiſtance of the external Air, and ruſhes forward to the Diſtance of fifteen or twenty Foot. In this manner the Fire, which burns, and is kept quiet under a Heap of Aſhes, by the Liberty, which a thouſand little Paſſages leave it of getting out into the Air, and of borrowing ſome aſſiſtance therefrom; that Fire, I ſay, when it receives a few Drops of Water round it, dilates them, lifts them up, and with them the Coals and Cinders. For this Reaſon it is, that the ſubterranean Fire, which, if alone, would roll round or through a ſmall flint without diſplacing it, being join'd to the Air and Water, lifts enormous Maſſes, ſhakes whole Regions, pieces the Ground, makes Rocks mount into the Air, and overthrows whole Mountains. A Simile will bring this to a ſufficient Degree of Evidence.

A Croud of Boys ſee at a diſtance Fruits that look very well. To ſee and covet them, is with them one and the ſame Thing. They firſt of all ſurvey all round about. Not a Soul to trouble them. But a Hedge parts them from the Object of their Deſires. How is this Barrier to be got over? In vain do they apply their Hands and Sticks to the Hedge; the Sticks go through; their Hands are ſcratch'd; Tears flow, and nothing has as yet been removed. They perceive a Harrow raiſed againſt the Hedge; and by the Advice of the beſt Genius among them, they all in concert apply their Sticks againſt the Bars that join the Pieces of the Harrow. They work ſo hard with their Feet, their Arms, and the whole Weight of their Bodies bearing againſt the Sticks, that all theſe little forces united, which were of no Effect when they could act but in a ſingle Point, now puſhing againſt the

Hedge by the whole Breadth of the Harrow all at once, they make a Breach in the Hedge, and go a plundering without Controul.

The Harrow gives theſe Children no manner of Strength, but it unites and improves forces, which being diſunited were render'd unpowerful. So when the Fire, aſſiſted by the Air, drives before it Surfaces of hard or maſſy Elements, ſuch as Salt, and Water, which cannot be admitted through the Apertures, that would yield a Paſſage to the Fire, then does it make the moſt horrid and dreadful Havock, and overthrows, bruiſes or ſcatters by that means, what it would have ſingly gone through, by a ſteady Efflux, and without damaging any thing.

Therefore, though the Elaſticity of the Fire be not always ſenſible, yet it is always effective, and it is from that Elaſticity modified or aſſiſted by the other Elements, that we may deduce the ſeveral Actions of Fire. Let us collect all we ſaid about it, and form a ſort of Dictionary of it, that may the better unravel the Whole, and fix it in Memory. The Actions of the Fire are to kindle, to increaſe, to ſmoak, to ſhine, to blaze, to crackle, to ſparkle, to aſcend, to evaporate, to blacken, to dry, to melt, to vitrify, to calcine, and to be extinguiſh'd.

The Dictionary of Fire.

The Fire *kindles*. Not that it takes Birth where it did not exiſt; but becauſe it gathers and becomes active where it was at reſt, and by a borrow'd Help becomes victorious where it was chain'd up.

The Fire *increaſes*, either in Quantity or Celerity, or both ways at once; and that by five principal Means. 1. By the Impulſion of the Light, eſpecially when it's Rays are collected in one and the ſame Point, or on the ſame Parcel of Fire. 2. By the Impulſion of the ſprings of the Air, eſpecially when they tend to the ſame Place. 3. By the Affluence of the Oil and of the Fire contain'd in freſh Air. 4. By the Junction of the Fires contain'd in combuſtible Matters, and eſpecially in oily Juices. 5. By the Narrowneſs of the Space, within which a great Quantity of Fire is confined and accelerated between Surfaces of Water and Salt.

It *ſmoaks*, by carrying off the Waters and other Particles, which it is capable of raiſing, and among which it is enveloped, being in too little a Quantity to incompaſs and overpower them, ſo far as to ſtrike immediately againſt the Body of the Light. The Smoak is ſo full of Fire, and it is ſo very true that the Fire forces it upwards in ſpite of it's Weight, that if you pour Water on a burning Log, you run the risk of ſcalding your Hand, in paſſing it through the Vortex of Smoak that riſes from it.

The Fire *blazes*, when it is ſtop'd within a narrow Space by a ſmall Quantity of Particles of Water, taken from the combuſtible Matters, and is there accelerated by the repeated ſhocks of the ſprings of the Air. A moderate Moiſture made up of Water, and Oil, properly is the Ground of Flame. Therefore the Coals, that have loſt almoſt all their Moiſture, yield little or no flame at all; and if the Fire of the flame is the ſtrongeſt of Fires, it is becauſe each Particle of Fire being barr'd by as many Particles of Water, their Vortices become the more rapid, and act the more violently, by the Help of the Surfaces of the Water, and by dilating leſs. Who would be apt to think, that it is this exact Meaſure of Water incloſed together with the Fire in all oily Juices, that makes up the flame of Sulphur, Wax, Tallow, Fat, and Oils? The Analyſis, which finds that Water again in them, leaves us no Room to doubt of the wonderful Caution, which has for our ſake been lodged in the Cells of Oil, Principles ſo different from one another, and has render'd them ſo very active and powerful, by the exact Proportion of their reſpective Quantities. But the Water and Fire of the Oils, when diſingaged by an external Fire, and all ſorts of flames in general, acquire a new Degree of force, when the Air joins to them by it's Agitation and conſtant Renewal. We need not, in order to convince ourſelves of this, have recourſe to the prodigious force, which a perpetual Blaſt always directed to the ſame Point, gives to the Lamp of an Enameller. The Uſe of our common Bellows is ſufficient to inform us, that the Fire, ſtrengthen'd by the ſhocks of the Air towards a ſmall Maſs of Fire, ſpreads through, and in all the Outſides of the Particles of Water, and of other Elements, which it carries off from the combuſtible Matters, and by ſhewing itſelf, hinders them

them from being ſeen; whereas that Brightneſs ceaſes, when the Multitude of the aqueous Particles is too abundant, and when the Fire incloſed within the Maſſes of Smoak, it drives away, does no longer act immediately on the Body of the Light.

Smoak is a flame begun, and the one is ſo little different from the other, that the leaſt Increaſe, either of the Quantity, or of the Celerity of the Fire, is ſufficient to turn the Smoak into flame. If you bring a Wax-candle juſt put out, near another that is lighted, holding the ſmoaking ſnuff a little lower than that on Fire; ſo ſoon as the Smoak of the firſt, carried by the flow of the Air, ſhall touch the flame of the other, the flame will ſpread both without and within that Smoak, and creep as it were into it, deſcending towards the extinguiſh'd Match, which it will immediately light again.

The Fire *ſhines* without either Smoak or Blaze, when it finds in the Body it conſumes, few or no aqueous Particles that ſtop it; ſo that it flows off, and is more eaſily diſperſed. That Brightneſs, free from Smoak and flame, is obſerved in all combuſtible Matters, after they are reduced to a Coal by the Diſſipation of their Moiſture.

The Flame therefore is properly nothing but a middling kind of Smoak, on which the Fire prevails, notwithſtanding the perpetual Oppoſition of the Water that ſtops it. For this Reaſon it is, that the Fire of a Forge becomes ſo very bright, when after it has been contracted and damp'd by the Water of the whiſp, it gets the better, and carries off that Water. For the ſame Reaſon, when the Fire ſeizes on a Tun of Oil, or ſome other Maſs of Fat or oil Juices, if ſome unexperienced Hand happens to pour Water upon it in order to put it out, the Fire, inſtead of being thereby abſorbed, divides and overpowers it, with an Expanſion of Deflagration extremely bright, and capable of firing every thing in the Neighbourhood thereof.

The Fire *crackles*, when it violently lets looſe ſome Particles of Air impriſon'd between Laminæ of Salt. There it does in little, what it does with a great Noiſe in Gun-powder, and in the *Pulvis fulminans*.

It *ſparkles*, when it is ſtrong enough to diſperſe ſome ſmall Parcels of the combuſtible Matter wherein it is incloſed. Such are the Parcels of pounded Coal it ſucceſſively cauſes to iſſue out of a Squib or Rocket.

The Fire *riſes*, or always tends to that Direction. For though it violently ſpreads on all ſides, and gets to the Bottom, as well as the ſides of the Bodies it conſumes, when compoſed of many very elaſtic Vortices, and aſſiſted by the Elaſticity of the Air, it has beſides a natural and ſenſible Tendency to go off from the Earth, let that Tendency be look'd upon as the primitive Impreſſion of him, who made every Thing as he pleaſed, or as only the Reſult of leſs Heavineſs; whence it happens that the maſſier Bodies place themſelves below it. However, that Effort, which the Fire makes to get above, carries along with it the Matters it has divided, with all the Air it has either unbent or dilated. The Parcels of Water, of Tallow, or Wax, and the heated Air ſpreading upwards, make a more remote and more contracted Air, which is always charged with a little Water, to return on every ſide the flame. The Spring of it being brisker, that Reflux of Air is the chief fewel of the Fire, both from the Conſtraint it is retain'd in, and the perpetual Supply of the Water it ſuſtains, and of the Oils, which the Water carries every where upon it's Globules.

The Fire *blackens* what it has not the force of either conſuming or deſtroying. When it has driven off all the Moiſture of a Piece of Wood, it circulates in a thouſand and a thouſand ways through the Texture it cannot divide; and when it is diſſipated, the Wood is then pierced with ſo many Holes, that the Light is therein abſorbed, and no Part of it is beaten back by Reflexion, but that which is neceſſary to render the form of that Body viſible, in which the black Colour conſiſts. A learned *Engliſhman* *, famous for his Application in perfecting Microſcopes, judging of the Quantity of the great Pores, which the Surface of a Coal an Inch in Diameter contain'd, by the Number he could reckon in the eighteenth Part of an Inch, found, that that Diameter contain'd above ſeven millions ſeven hundred and eighty thouſand. What muſt then be the Number of the imperceptible Pores, and what a vaſt Diſſipation muſt the Light ſuffer in ſo many Apertures?

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* Hooke's Micrography.

The Fire *evaporates*, or cauſes the Moiſture it meets with to evaporate. When it has Strength enough to hurry with it the little Maſſes of Water that oppoſe its Motion, it fills the Air with them, and diſperſes them to Diſtances far ſuperior to the Region of the Clouds. The whole Space, from the Top of the Atmoſphere down to the Earth, is full of theſe Bubbles of Water. The Light, the Fire, the Air, and the Water, are evidently one within another, exerciſe each of them its proper Action, without Damage to each other, and, contrary to Imagination, work in Concert for the Service of the Earth.

The Fire *dries* and hardens all thoſe Bodies, the Moiſture of which it evaporates; but it performs this Operation only by the Aſſiſtance of the Air. Wherefore a ſharp Wind in a Manner dries and burns as Fire does; becauſe by carrying away the Water in its Courſe, it contributes to draw again near each other, and to harden the Particles of the Surface, which the Water quits. The Froſt alſo hardens; but in a very different Manner. It does it, not by carrying away, but by contracting the Water by the Efflux of the Fire. And when this Contraction of the Fluids happens in the Body either of Plants or of Animals, it compreſſes, it torments and breaks there the little Veſſels neceſſary for the Nutrition; whence it happens, that a Leaf, which has been frozen, having no more its Veſſels placed as before, rots at the Thaw. And if the Sun ſhines thereupon, and draws off all the Moiſture of the rotten Leaf, the Texture of it is totally deſtroy'd, and it is no more than a Quantity of Duſt.

The Fire makes *fluid*, or puts into a State of Fuſion, the Water, the Oil, all the oily Juices, and generally all Metals. It in ſome Sort communicates its Nature to them; ſince it puts them in a State of Fluidity, and its communicating that Quality to them, rather than to the other Bodies, is, becauſe being more ſimple, and made up of uniform Particles, they are the more proper to retain it in their Interſtices wherein it whirls, diſplacing theſe little Maſſes, and making them tumble one upon another. Which ſeems the truer, becauſe when it ſpreads therein in a greater Quantity, or with a greater Violence, it makes way through, ſcatters them, and makes them evaporate. Thus it exalts and refines Salt, Mercury, Lead, and all Metals; ſince Gold itſelf, weighty as it is, inſenſibly is diſperſed in a great Fire, and it proves at length to have loſt ſomething.

The Fire *vitrifies* and *calcines*. It vitrifies what is Sand, and calcines what is Earth or true Soil. The Diverſity of theſe Operations does not proceed from the Fire, whoſe Action is always the ſame, but from the Nature of the Matters, on which it acts; and if we ſee it in the ſame Maſs of Mineral oftentimes diſcharging the three Functions of melting, calcining, and vitrifying, it is becauſe it at once finds metallic Particles to melt, Sands to vitrify, and Earth to calcine. The Fire produces nothing there, but it diſplays what was therein, and will never cauſe the Metal to become Earth, or the Sand to turn into Aſhes, or the Aſhes to be tranſmuted into Metal. Theſe things may be united or ſeparated. One may predominate over the others; and the whole may flux and be carry'd away with the melted Metal. The Sand may envelope both Earth and Metal in a Vitrification that hides them; but each of them invariably keeps its own Nature; and if in many chymical Operations * ſome certain Matters become much heavier, by paſſing through the Fire, it is not at all becauſe the Fire or the Air are converted into theſe Matters, but becauſe they incorporate with them Maſſes of Water or of Salt, and more particularly oily Juices, wherewith the Air and the combuſtible Matters are impregnated.

The Fire itſelf, when it *goes out*, (and this is the laſt of its Actions remaining to be explain'd) the Fire, I ſay, is then neither dead or deſtroy'd. It ſcatters; it is diſperſed; it does no longer act as it did before, but is ſtill what it was in all Reſpects. Have you a Mind to extinguiſh it in a burning Log? You muſt abſorb that Fire by a Quantity of Water ſuperior to it. It is no longer in the Log; but it wholly ſubſiſts in the Water, which it raiſes into a Fume. Would you extinguiſh it in a Charcoal-pit, where it burns the Wood abandon'd to its Fury under a Heap of the Earth, and which it devours by the Aſſiſtance of a few Holes, through which it is ſupplied with Air, in order to renew it and keep it up conſtantly in the wood? You need only ſtop the ſaid Holes, whereby you rob it of all Correſpondence with the Air. So ſoon as it is deſtitute of the Company of that groſs Element that gave it Strength, and with the Denſity whereof it violently ſhock'd the Texture of the wood, it immediately gets through the Maſs of Earth, that cover'd the Coals. It has no more Activity; becauſe it ſpreads and gets away without any Return. But it is in it's Diſperſion all that it was, when a continual flow of freſh Air repel'd and nouriſh'd it in one and the ſame Place.

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* See Boyle, de Ponderabilitate Flammæ.

From all theſe facts, Sir, which I have thus united before your Eyes, and from an infinite Number of others, which Experience will afford you every Day, there reſults a Truth, which I take to be capital in Phyſics, as well as in Moral Philoſophy; *viz.* that God has put between Man and all the Objects around him, ſuch an evident Relation of Uſefulneſs, and an appointment of Services ſo eaſy to be diſcern'd, that in the Heaven, as well as on the Earth, the Spectacle of Nature ſpeaks to him of nothing but the tender Regard and affection of his Creator towards him. Every where between the Heaven and the Earth, between the Light and the Atmoſphere, between the Fire or the other Elements and Man, we obſerve the ſame Unity of Intention, and the ſame Correſpondence, which we remark between our appetite and our food, between our Teeth, which grind and faſhion our Meats, and the Stomach that digeſts them. Phyſics are then an admirable School of Piety; and all the Sciences of any particular Purport may become ſo many Informations to the Mind; ſince in the admirable artifice of each individual Piece, there is nothing, which we more evidently diſcern, than a conſtant Intention in the Creator, of being every way beneficial to us.

Hitherto we have beſtow'd our attention on only what ſhews itſelf apparently, and on what requires no great Effort to be apprehended and conceived. But this ſo uſeful and ſo affecting Science contains ſome other Particulars, the Diſcovery of which muſt needs have required a great deal of Time and Trouble. Inſtead of informing you of them in a ſcholaſtic Manner, and by abſtruſe Arguments, let us here borrow the aſſiſtance and charms of Hiſtory. Let us from age to age trace Men in all their ſeveral wants, and the works of great Men, in the Endeavours they have made to be of ſervice to Mankind. Let us, in a Series of hiſtorical Dialogues, examine firſt, what Experience has procured us, on the Certainty of which we may depend, and then what Benefit may be drawn from the Syſtems of Philoſophers. This method of ſtudying Phyſics will be more to your liking; and methinks I muſt not here heſitate about confining your Mind to a didactic Order, or ſuiting my Method to your Inclinations.

The whole Survey of Nature has already convinced you, that all the Parts, which compoſe it, are the work of a ſingle Intention, which created, united, fitted them up, and made them relative and concurrent to one and the ſame End. Let us now ſee in the Hiſtory of the Study, which Man has made of them, how far the Progreſs is carried. Let us enrich ourſelves with their Labours. This Hiſtory, by informing us of many particular and practical Truths, may facilitate to us the Clearing and Solution of an important Queſtion, *viz.* whether the Diſcoveries, made by Men in ſix thouſand Years paſt, give us any Room to think, that one ever might arrive at knowing the Groundwork, and Nature of what ſurrounds us, or to think, that God granted us no more Light and Knowledge than what is ſufficient to rule our Minds, and ſupply our Hands with proper Employment.

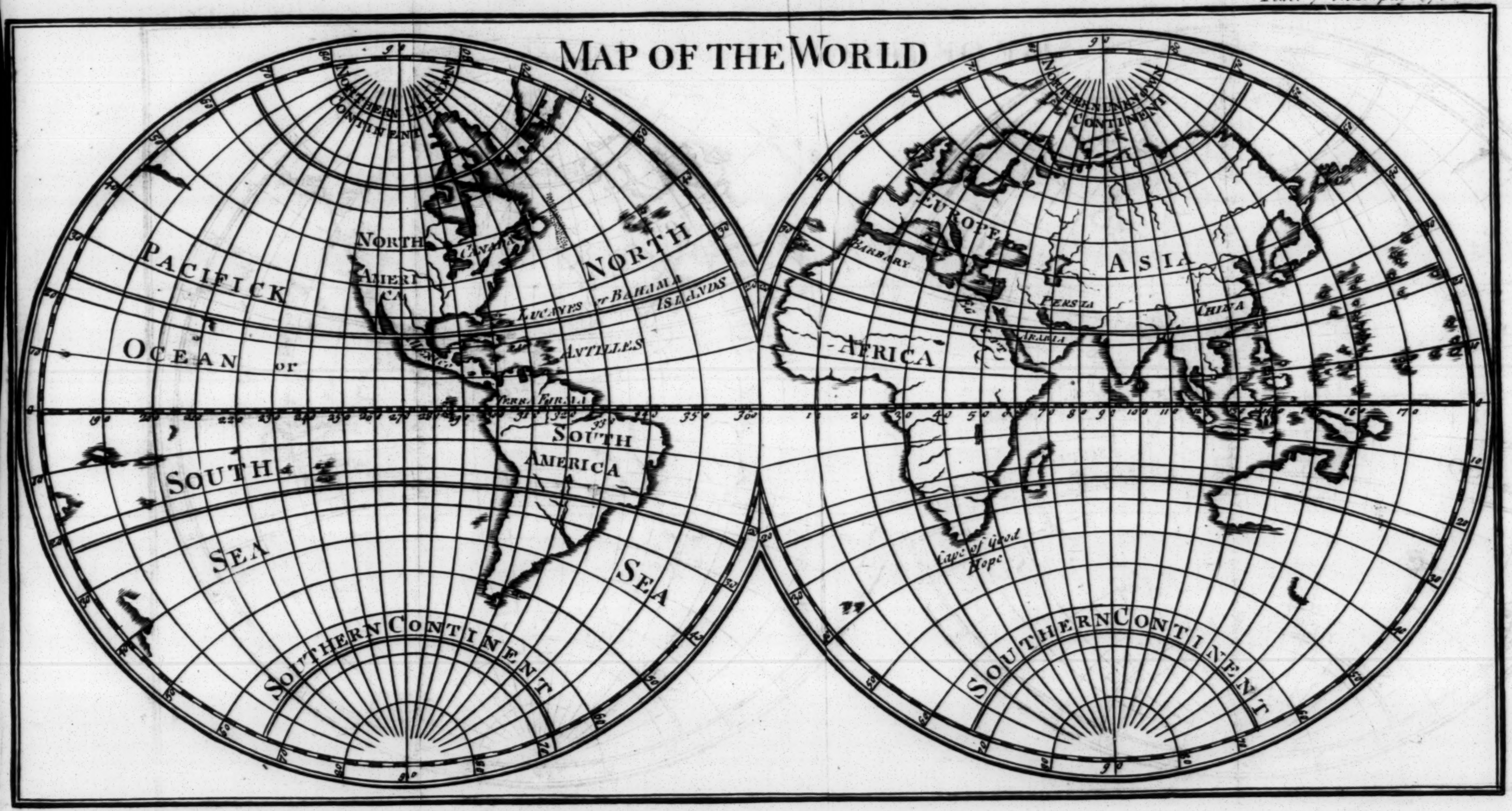
Spectacle de la Nature.

THE
SEQUEL
OF THE
FOURTH VOLUME.

Containing the

HISTORY
OF
Experimental PHYSICS.

MAP OF THE WORLD



THE HISTORY OF EXPERIMENTAL PHYSICS.

The Invention *of the* ZODIAC.

DIALOGUE I.

ASTRONOMY, or that Part of Phyſics employ'd about regulating the Order of our Days by the Inſpection of the Heavens, as being the moſt neceſſary, was alſo the firſt cultivated. When *Noah*'s Children had quitted the Rocks of the *Gordyan*, and begun to form a numerous Nation in the wide Plains of *Shinar*, the Neceſſity of providing for their Food, and that of their Flocks and Herds, obliged them to go a good Way from each other. But though they knew that God had deſign'd them to re-people the Earth, they obſtinately reſolved to keep all together; and leſt they ſhould be obliged to diſperſe, they began to build a City, and a Tower ſo very high, that it might be ſeen at a vaſt Diſtance, and ſerve as a Signal to gather themſelves again together. * From that Time the unavoidable

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* The *Hebrew* has it thus. *Let us make us a Signal*, (Shem) *leſt we ſhould be diſperſed through every Region.* The Word (*Shem*) has produced σῆμα and σημεῖον, which in *Greek* equally ſignify *a Mark*, *a Sign*, or *a Name.* But thoſe, who tranſlated it *let us make us a Name*, *let us render our Name famous*, were forced to put *Antequam* inſtead of (*Pen*) *Ne forte*, and to tranſlate it in theſe Words; *before we be ſeparated on all Sides.* Which does no longer agree with the original Text, nor expreſs the Undertaking, which was directly oppoſite to God's Purpoſe, *viz.* to re-people all the Earth by the Family of *Noah*.

Neceſſity of ordering the Affairs of Mankind, and of ſettling the Times for the Operations of Husbandry, obliged them to agree upon ſome convenient Regulations, and a certain Method of meaſuring and calculating of Time. They moſt naturally made uſe of the periodical Revolutions, which they obſerved in the Heavens. The Return of the ſame Motions, and the Renewal of the ſame Phænomena were inſenſibly pitch'd on, as the moſt fit Terms to fix Expirations, or to mark out the Times of plowing and ſowing, becauſe the Returns were regular, and beſides, obvious to every Eye.

The Moon the firſt Rule of Mankind.

The plaineſt Meaſure of Time they could employ at firſt was that, which the Moon offer'd them. By every Day changing very ſenſibly the Place of both its Riſing and Setting, by varying its Form from Day to Day, and by beginning afterwards a new Order of Changes intirely like it at once became a public Rule, and afforded them an eaſy kind of Reckoning. They might date either from the New or the full Moon, or from ſuch or ſuch a Quarter. They might tack ſeveral Quarters together, or as many complete Lunations as they thought fit. Thus without the Help of Almanacks or of Writing, every Body could find in the Heavens a Warning or *Memento* of what he had to do. All Families, however remote, gather'd together without Miſtake at the appointed Term; and inſtead of meaſuring Time by a Number of Days, which their Reſemblance might confound, or the Series or Sequel of which, once loſt, could not be again found, they were exempted from all Cares that Way, by referring the ſhort and long Durations to the Courſe of the Moon, which ſhew'd them from one Day to another, by a new Sign, what Time was already expired from the Beginning of one Term, and what Time remain'd till the following.

The firſt Men, affected by the Conſideration of the twofold Service the Moon did them, by enlightening the Night, and by regulating all Mankind, conſecrated the Uſe they made of its Phaſes by a Holiday or Feaſt, which they ſolemnized at every Time of its Renewal. The *Neomenia* ſerved in a plain and commodious Manner to regulate the public Exerciſe of their Devotion. But if they regularly gather'd together to make their Sacrifices, and lovingly to viſit each other at the Return of every new Moon, that Worſhip and thoſe Holidays were no way relative to the Moon itſelf. God was the Object of them; and the Moon had no other Share therein, but that of putting Men in Mind of celebrating them.

The Stars had not as yet received the Names they now go by. Without taking Notice of the ſeveral Conſtellations, under which the Moon is ſucceſſively placed within the Space of its monthly Courſe, Men were contented with only determining its Progreſs, by the Variety of its Appearances; and inſtead of employing Calculations, as has been ſince done, to mark out the preciſe Inſtant of its having over-taken the Sun a-new, under which it had paſs'd nine and twenty Days before; the Aſtronomy of thoſe Times was contented with the bare Teſtimony of the Eyes, and they reckon'd the New Moon from the Day it could be perceived. It was in order to get Intelligence of it, without Hindrance, that they aſſembled and met together in high Places, or in Deſarts remote from the Habitations of Men; that no Obſtacle or any Thing might ſcreen the Horizon from them. When the Creſcent had once been ſeen, they ſolemnized the *Neomenia*, or the Sacrifice of the new Moon, which was ſucceeded by a Repaſt, where all the Families chearfully, and with Simplicity and Candour, eat what had been offer'd to God, and conſecrated by Prayer. When any notable Event occaſion'd the Inſtitution of ſome annual Feaſt, they very often join'd it to the *Neomenia*, which was the uſual Day of Aſſembly. The new Moons, which concur'd with the Renewal of Seaſons, and to which our four Emberweeks do ſtill correſpond, were the moſt ſolemn of all. That Cuſtom of meeting together in high Places or in Deſarts, that of keeping the new Phaſis, that of celebrating the *Neomenia* by a Sacrifice and by Prayers, in particular, the Solemnity of the new Moon, which concur'd with the Sowing, or follow'd the entire gathering of the Fruits of the Earth; finally, the Repaſt and the Songs, which came after the Sacrifice, are Uſes, all of which were, from this common Source of Mankind, handed down to all the Nations of the Univerſe. All theſe Cuſtoms we find again among the *Hebrews* [*], the *Egyptians* (†) and the *Arabians* [||], from whom they, together with *Mahometiſm*, were, deliver'd down to the *Perſians* [‡] and the *Turks* [§]. The ſame Uſages were common to the *Greeks* [**] and the *Romans* [††], to our Fore-fathers the *Gauls* [||||], and to Nations, which had no manner of Communication with each other. They were found again amongſt the *Charybs*, and ſome other *American* Nations [‡‡].

Scripture abounds with facts, which evidently prove, that the Cuſtom of ſacrificing on high Places was eſtabliſh'd among the *Hebrews* as well as the other Nations, even before the Law, and that it even ſubſiſted in *Iſrael* ſince, and in ſpite of the Law. The Law itſelf teſtifies its Antiquity, by forbidding it, as capable of imparing the Unity of the Worſhip. That of the *Neomenia*, as antient and univerſal

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(*) The Requeſt, which the *Hebrews* made to go and ſacrifice in the Deſarts, did not ſurpriſe *Pharaoh*. It was an univerſal Practice. As to the high Places, and the *Neomenia*, ſee 1 *Kings* ix. & xx, *&c. paſſim in tota Script. Horatii Serm. L.* 1. *Sat.* 9. *triceſima Sabbata*, the Feaſt of the thirtieth Day. It is the *Neomenia*, which comes again after twenty nine Days. *Jerem.* xliv. 17. and *Buxtorf. Synagog. Judaic.* c. 17.

[†] *Maimonid. Ductor Dubitantium, lib.* 3. c. 46.

[||] *Hiſtor. Arabic.* c. 11. and *Hottinger. Hiſt. Orient. lib.* 1. *c.* 8.

[‡] *Hackluit*'s Voyages, Vol, 2. pag. 399.

[§] *Anton. Geuffræus de Turcar. Relig. lib.* 2. *p.* 53.

[**] *Herodot.* in the Life of *Homer. Meurſius Græc. feriata, voce* Νουμηνία. *Samuel Petit. in Leg. Attic. p.* 35.

[††] *Macrob. Saturnal. lib.* 1. *cap.* 15. *Plutarch. lib. e vit. Ære al. idem in vita Æmi.* & *Horatii carm. l.* 3. *od.* 23.

[||||] Religion of the *Gauls*. In the antient Figures of the Ceremony of the *Miſletoe*, the *Druid* wears a Half-moon; becauſe it was at the *Neomenia* the Ceremony was perform'd.

[‡‡] *Alexand. Geraldin. Itinerar. lib.* 9. *Huet. Demonſtr. Evangel. p.* 84.

as the other, was preſerved and regulated by the Law. The Learned obſerving between the *Hebrews* and the *Heathens* ſo great a Reſemblance as to their Sacrifices, their reſorting to high Places, and their *Neomeniæ*, have enquired into the Cauſe of this Conformity, and been divided into two Opinions equally deviating from Truth; but one of which, though falſe, yet is of no dangerous Conſequence, whereas the other is extremely ſo. The firſt conſiſts in thinking, that the Heathens took, both from Scripture and the *Hebrews*, the greateſt Part of their Practices, even to their very Fables, which are, ſay they, no more than ſome Particulars of the Sacred Hiſtory alter'd and diſguiſed. The other Opinion conſiſts in thinking, that the *Hebrews* received, from the *Egyptians* and the *Canaanites*, the whole Ground of their Law and Ceremonies, which tends to ruin Revelation. The firſt Opinion, though innocent, and very common, yet is unwarrantable; ſince the Heathens became acquainted with the Books of the *Hebrews* but very late, and that People, totally ſeparated from and unknown to other Nations, was on no Account fit to ſerve them as a Pattern. The other Opinion is no leſs abſurd, ſince the Law inſiſts, in the moſt particular Manner, on forbidding the *Hebrews* the Practices of the *Egyptians*, the *Arabians*, and the *Canaanites*. If the *Hebrews* and the Heathens agree together in the Practice of their Sacrifices, Purifications, and Libations, in their Inclination to gather together upon high Places, and in the Regularity of their *Neomeniæ*, a Grain of Sincerity will make us ſenſible, that the *Hebrews* are not indebted to the Heathens for theſe Cuſtoms, and that the Heathens did not borrow them from the *Hebrews*; but that both the *Hebrews* and the Heathens had them from the remoteſt Antiquity, and from the common Source whence they all ſprung, I mean from the Family of *Noah*, when the whole was contain'd in the Plains of *Chaldea*. This Point of Re-union, equally plain and certain, is the ſole unravelling of the Difficulties, which divided the Learned. The whole of Mankind, being gather'd round *Babel*, had already the Practice of the Sacrifices made before, and renew'd by *Noah* immediately after the Flood. For want of Writing, what Means could be more natural and more public, to call together to the Sacrifice a Multitude of Families diſperſed, than the Sight of the Decline of the Moon, and the Return of the New? It is even very likely, that the Sun, which before the Flood mark'd the Courſe and the Bounds of the Year, by the Diverſity of the Stars, under which he paſs'd, did it however without leaving the Æquator, and put no Difference between one Day and another, or one Seaſon and another. The Moon was then the moſt proper Means to mark out the Beginning and the Progreſs of Months; and *Noah*, when he fix'd the religious Meetings at the Time of the *Neomenia*, did but renew what was practiſed before the Flood. So the Fathers of all Nations having been long enough under the ſame Leader, in the ſame Place, united by the ſame Wants, the ſame Language and the ſame Practices; it is the plaineſt Thing in the World to think, that the Cuſtom of meeting in high Places, and at the Return of the new Moon, the Offering of the Fruits of the Earth, the Sacrifices, the common Repaſts and the Songs, are all Uſages, which have with them paſs'd through all the Earth. This is what they have conſtantly preſerved ever ſince their Diſperſion; and in every other Thing, they conſtantly proceed with making themſelves diſtinguiſh'd from each other. You are ſenſible, how this Agreement of all Nations in the religious Cuſtoms, which ſuited the firſt Ages, and their infinite Variations in all the reſt, concur to teſtify the Truth of *Moſes*'s Narration, and the perfect Knowledge he had of the Origin of Things.

Aſtronomy, in its Birth, had the Glory of regulating the firſt Form of public Worſhip. It was ever ſince ſtrictly united with Religion, to which, it from Age to Age render'd new Services in the Courſe of its Progreſs; and Aſtronomy degenerated into Impertinence, or into Superſtitions, only when Religion was perverted.

The Invention of the Zodiac.

After the Introduction, or, if you pleaſe, the Reſtitution of the *Neomenia*, by the Obſervation of the firſt Phaſis of the Moon, they apply'd themſelves to the fixing of the Beginning and the End of the Year, by which they had, Time out of Mind, taken Care to meaſure the Life of Man, and to mark the Diſtances of notable Events. If the Meteors and the Variety of Seaſons were not any more than the Rainbow known till after the Havock made by the Flood, the Succeſſion of Years became but the more ſenſible ſince that great Change. It was an eaſy matter for Men to reckon how many Harveſts they had got in; and, in the poetical Style, ſuch a Number of Springs or Summers are commonly underſtood by ſo many Years. But ſomething more than this was wanting, and Neceſſity brought Aſtronomy one Step forwarder.

Twelve Lunations one upon another, that is, twelve Revolutions of the Moon ſucceſſively, departing from and drawing again near the Sun, were not ſufficient to bring out the whole Courſe of a Year; and the Duration of thirteen Lunations exceeded the Year; for twelve times 29 Days are only 348, and thirteen times 29, are 377 Days; whereas the Year is only 365 Days and a few Hours. The ſeveral Revolutions, which the Moon makes in the Heavens, by ſucceſſively paſſing and repaſſing from Month to Month under certain Stars, being then not exactly contain'd a certain Number of Times in that which the Sun makes by paſſing pretty nearly under the ſame Stars, it was not poſſible to determine the Beginning and the End of the Year by an exact Number of Lunar Revolutions. They were then obliged, in order to know the preciſe Bounds of the annual Courſe of the Sun, carefully to examine what Stars were ſucceſſively obſcured or drown'd by the paſſing of that Globe, and what Stars, beginning to clear themſelves from it's Rays by reaſon of it's Remoteneſs, ſhew'd themſelves again before the Dawn of Day.

They might, 'tis true, have reſumed the Method of calculating, which was in Uſe before the Flood *. But it would have been inſufficient upon many Accounts. For, though the Sun did perhaps ſtill paſs under the ſame Stars as before; it's Fires, whoſe Influence was even and uniform before the Flood, had ever ſince been ſometimes brisker, ſometimes fainter. The Sun itſelf ſeem'd to change the Points of it's Riſing and Setting. It aſcended it's Meridian much higher at one Time than at another.

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* See the Letter at the End of the third Volume.

Theſe Novelties required new Obſervations, and they endeavour'd, not indeed to underſtand the Structure of the World, or the Reaſon of all theſe great Effects, but in the Heavens, to ſhew Men ſome perciſe Marks of the Progreſs of the Year, and ſome ſure Methods of regulating the Times of their Works. They obtain'd both theſe uſeful Points. The firſt, by making themſelves Maſters of the certain Knowledge of the Stars, under which the Sun paſſes, and which are in his way from the Moment he goes from any firſt Star, taken at Diſcretion, to the Inſtant of his coming again under the ſame. Secondly, By giving theſe Stars ſuch Names as might characterize what was peculiar to every Part of the Year, or what was actually done upon Earth, when the Sun was under ſuch or ſuch Stars. Aſtronomy, by this twofold Caution, was from it's Beginning a popular Science, and it made Heaven a Book always open, to which Mankind might come for Information.

The Diviſion of the Zodiac.

Antient Tradition has handed down to us the ingenious Manner, in which the firſt Men went about knowing exactly the Line, which the Sun deſcribes under the Heavens in the perpetual Changings of it's Place, and to divide the Year, into equal Portions. This Tradition is found again in two antient Authors, the one *Roman* * the other *Greek* †. The firſt attributes it to the *Egyptians*; the other, and more juſtly, to the firſt Inhabitants of *Chaldea*, which are the Fathers of Aſtronomy, as well as of all Mankind.

They every Day ſaw the Sun and the whole Heaven turning and paſſing from Eaſt to Weſt. In the mean time they obſerved, that the Sun, by a Motion peculiar to it, from Day to Day receded from ſome certain Stars, and took it's Place under others, always advancing towards the Eaſt. Whilſt the Moon was making twelve times that Revolution, the Sun made it only once. But ſhe began the Thirteenth again, before the Sun has as yet completed it's own. The Habit of dividing the Year into pretty near twelve Lunations, made them wiſh, that they had twelve Diviſions of a Year perfectly equal, or twelve

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* Macrob. in ſomn. Scip. l. 1. c. 21.

† Sext. Empiric. lib. V. adverſus Mathemat.

Months, which might be exactly equivalent to the Year itſelf, and which might as it were, be pointed at with one's finger in the Heavens, by ſhewing ſome certain Stars, under which the Sun paſſes during every one of theſe Months. Here is then the Method, in which they divided the Courſe of the Sun into twelve equal Portions or Collections of Stars, which are call'd *Aſteriſms* or Conſtellations. Our *Chaldeans* took a couple of braſs open Veſſels, the one pierced at the Bottom, and the other without any Orifice below. Having ſtopp'd the Hole of the firſt, they fill'd it with Water, and placed it ſo as that the Water might run out into the other Veſſel, the Moment the Cock ſhould be open'd. This done, they obſerved, in that Part of the Heaven where the Sun has it's annual Courſe, the Riſing of a Star, remarkable either for it's Magnitude or Brightneſs; and at the critical Inſtant it appear'd on the Horizon, they began to let the Water flow out of the upper Veſſel into the other, during the reſt of the Night, and the whole following Day, to the very Moment when the ſame Star, being come to the Eaſt again, began to appear a-new on the Horizon. The Inſtant it was again ſeen, they took away the Under-veſſel, and threw the Water that remain'd in the other on the Ground. The Obſervers were thus ſure of having one Revolution of the whole Heaven, between the firſt Riſing of the Star and it's Return. The Water, which had flow'd during that Time, might then afford them a Means of meaſuring the Duration of one whole Revolution of the Heaven, and dividing that Duration into ſeveral equal Portions; ſince by dividing that Water itſelf into twelve equal Parts, they were ſure of having the Revolution of a twelfth Part of the Heaven during the Efflux of a twelfth Part of the Water. They then divided the Water of the under-veſſel into twelve Parts perfectly equal, and prepared two other ſmall Veſſels capable of containing exactly one of thoſe Portions, and not a Drop more. They again pour'd into the great Upper-veſſel, the twelve Parts of Water all at once, keeping the Veſſel ſhut. Then they placed under the Cock, ſtill ſhut, one of the two ſmall Veſſels, and another near it to ſucceed the firſt, ſo ſoon as it ſhould be full.

All theſe Preparations being ready, they the very next Night obſerved that Part of the Heaven, towards which they had for a long while remark'd that the Sun, Moon, and the Planets, took their Courſes, and ſtay'd for the Riſing of the Conſtellation, which is ſince call'd *Aries*. The *Greeks*, perhaps, gave that Name to ſome other Stars than thoſe, which went before the Flood. But this Inquiry is not neceſſary at preſent. The Inſtant *Aries* appeared, and they ſaw the firſt Star of it aſcending, they let the Water run into the little Meaſure So ſoon as it was full, they remov'd it, and threw the Water out. in the mean time they put the other empty Meaſure under the Fall. They obſerved exactly, and ſo as to remember very well, all the Stars that roſe during all the Periods, which the Meaſure took in filling; and that Part of the Heaven was terminated in their Obſervations by the Star, which appear'd the laſt on the Horizon, the Moment the Meaſure was juſt full; ſo that by giving the two little Veſſels the Time neceſſary to be alternately fill'd to the Brim three Times a piece during the Night, they had by that Means one half of the Courſe of the Sun in the Heaven, that is, one half of the Heaven itſelf; and that Half again was divided into ſix equal Portions, of which they might ſhew and diſtinguiſh the Beginning, the Middle and the End, by Stars, which from their Size, Number or Order, were render'd diſtinguiſhable. As to the other half of the Heaven, and the ſix other Conſtellations, which the Sun runs over therein, they were forced to defer the Obſervation of them to another Seaſon. They ſtood till the Sun, being placed in the Middle of the now known and obſerved Conſtellations, ſhould leave them at Liberty to ſee the others during the Night.

Doubtleſs ſome Precautions are neceſſary, not to miſtake as to the Fall of the Water, which muſt flow more ſlowly in Proportion as its Maſs is leſs high; however, after having by this or ſome ſuch Means, made themſelves ſure of the great annual Courſe, which the Sun faithfully follows in the Heavens, and of the Equality of the Spaces, fill'd by the twelve Collections of Stars that Limit that Courſe, the Obſervers thought of giving them Names. They in general call'd them the *Pauſes*, the Stations or the Houſes of the Sun, and aſſign'd three of them to each Seaſon. They then gave each Conſtellation a peculiar Name, whoſe Property did not only conſiſt in making it known again to all Nations, but in declaring at the ſame time the Circumſtance of the Year, which was of Concern to Mankind, when the Sun ſhould arrive at that Conſtellation.

Formerly, Sir, I obſerved to you, (but this is the proper Place of remembering you of it) that the Names, by which the twelve Aſteriſms of the great annual Circle actually go, had been taken from the moſt important Events, that happen either in the Heavens or on the Earth, as the Sun ſucceſſively takes his Place under every one of them.

By a particular Care of Providence, the Dams of the Flocks commonly happen to be pregnant about the End of Autumn. They bring forth during the Winter, and in the Beginning of the Spring. Whence it happens that the young ones are kept warm under the Mother during the Cold, and afterwards eaſily thrive and grow active at the Return of Heat. The Lambs come the firſt; the Calves follow them, and the Kids fall the laſt. By this means the Lambs, grown vigorous and ſtrong, may follow the Ram to the Fields as the fine Days come on. Soon after the Calves, and at laſt the Kids venture abroad, and by increaſing the Flock begin to augment the Revenues of their Maſter.

The Conſtellations of the Spring.

Our *Chaldean* Obſervers, ſeeing that there were during the Spring no Productions more uſeful than Lambs, Calves and Kids, gave the Conſtellations, under which the Sun paſſes during that Seaſon, the Name of the three Animals, which enrich Mankind moſt of all. The firſt was named *Aries*, the ſecond *Taurus*, the third *the two Kids* (*Gemini*), the better to characterize the Fecundity of Goats, which commonly bring forth two young ones rather than one, and an Abundance of Milk more than ſufficient to nouriſh them.

The Conſtellation of the Summer.

The groſs of Mankind, united in the Plains of *Irack*, had already very often remark'd that there was a Point, to which the Sun raiſed itſelf in its coming towards them, but which it never exceeded; and that it afterwards ſunk daily, in receding from them for ſix Months together; till it arrived at another Point a great way under the firſt, but below which it never deſcended. This Retreat of the Sun, made very ſlowly, and always backward, gave the Obſervers the Occaſion of diſtinguiſhing the Stars, which follow the two *Kids*, or *Gemini*, by the Name of the Animal that walks backward, *viz*, the *Crab*. When the Sun paſſes under the next Conſtellation, it makes our Climate feel ſultry Heats, but chiefly the Climates where Men were at that Time all united. When Poets attribute to that Conſtellation the Fierceneſs [*] and Raging of the Lion, of which it bears the Name, it is very eaſy to gueſs at what might determine that Choice from the Beginning. Soon after, the Houſing of the Hay and the Corn is entirely over throughout the Eaſt. There remain on the Ground only a few Ears ſcatter'd here and there, which they cauſe to be glean'd by the leaſt neceſſary Hands. This Work is left to the youngeſt Girls. How then could they repreſent the Conſtellation, under which the Sun ſees no longer any Crops on the Ground, better than by the Name and Figure of a young Maid gleaning? The Wings you ſee her have in the Spheres, are Ornaments added of later Date, after the Introduction of Fables. The Virgin, which follows the Lion, is certainly no other than a gleaning Girl, or, if you will, a Reaper; and leſt one ſhould miſtake her Functions, ſhe beſides has in her Hand a Cluſter of Ears. A very natural Proof of the Origin I here attribute to her.

The Conſtellations of Autumn.

The perfect Equality of Days and Nights, which happens when the Sun quits the Sign of *Virgo*, cauſed Aſtronomers to give the next Sign the Name of *Libra*, that is, of a Balance. The frequent Diſeaſes, which the Sun leaves behind him, or cauſes by his retiring, procured the next Sign the Name of *Scorpio*; becauſe it is miſchievous, and drags after it a Sting and Venom. Towards the End of Autumn, the Fall of the Leaf expoſes wild Beaſts, leaving them leſs cover'd. Vintage and Harveſt are over. The Fields are free, and it is of ill Conſequence to ſuffer the Propagation of Beaſts at the Approach of Winter. All then invites us to hunt, and the Sign, in which the Sun is at that Time, has from thence obtain'd the Name of *Sagittarius*, that is, the Archer or Huntſman.

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[*] Furit & ſtella veſani leonis. Horat. Carm. l. 3. od. 29.

The Conſtellations of the Winter.

What is the proper and diſtinctive Character of the wild Goat, or *Capricon*, of which the firſt Sign of Winter has the Name? It is to look for it's Food getting from the Foot of the Mountains to the higheſt Summit, and always climbing from Rock to Rock.

Dès que les Chevres ont brouté,
Certain eſprit de liberté
Leur fait chercher fortune. Elles vont en voyage,
Vers les endroits du pâturage
Les moins fréquentés des humains.
Là, ſ'il eſt quelque lieu ſans route & ſans chemins,
Un rocher, quelque mont pendant en précipice,
Elles y vont promener leurs caprices.
Rien ne peut arrêter cet animal grimpant *.

La Fontaine.

The Name of *Capricorn* was then fit to inform Men of the Time when the Sun, having reach'd the loweſt Verge of it's Courſe, was ready to begin to aſcend again towards the higheſt, and to continue to do ſo for ſix Months together. This is quite the reverſe of the Crab (*Cancer*); and the happy Concurrence of the oppoſite Characters of theſe two Animals, is a Proof of what directed the firſt Obſervers in the Impoſition of all theſe Names †.

Aquarius and *Piſces*, without any Difficulty mark, out the Rainy-ſeaſon, and the Time of the Year when Fiſhes, fatter and nicer than in any other Time, bring on again the Profit and the Pleaſures of Fiſhing.

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* Capricornus ex infernis partibus ad ſupera ſolem reducens, capræ naturant videtur imitari, quæ dum paſcitur ab imis partibus, ſemper prominentium ſcopulorum alta depoſcit. Macrob. Saturnal. l. 1. c. 21.

† Ideo autem his duobus ſignis, quæ portæ ſolis vocantur, Cancro & Capricorno, hæc nomina contigerunt, quod Cancer animal retro atque oblique adit; eademque ratioue ſol an eo ſigno obliquum (ut ſolet) incipit agere retrogreſſum. Capræ vero conſuetudo hæc in paſtu videtur, ut ſemper altum paſcendo petat; ſed & ſol in Capricorno incipit ab imis in alta remeare. Saturnal, l, 1, c, 17.

It may be remark'd, that of the twelve Conſtellations, there are ten, the Names whereof are borrow'd from ſeveral Animals; which cauſed Aſtronomers to give the annual Circle, which they compoſe, the Name of *Zodiac*. It is as much as if you ſhould ſay, the Circle of Animals.

By this very plain Induſtry, Men acquired a very new Method of meaſuring Times, and of regulating all their Works. They already knew, without any Trouble or Caution, how to regulate the Order of their Feaſts and common Buſineſs, by Inſpection only of the Phaſes of the Moon. From the Knowledge of the Zodiac, they obtain'd an exact Knowledge of the Year. The Conſtellations became to them ſo many very ſignificant Signs, which, both by their Names and reſpective Situations, inform'd them of the Order of their Harveſts, and of the Cautions they were to take, in order to bring them about, openly and daily ſhewing them how long they were to ſtay for them. The People were neither obliged to caſt up the Days, or mark out the Order of Times to regulate themſelves. A dozen of Words applied to twelve different Parts of the Heaven, which every Night revolved before their Eyes, were to them a Part of Knowledge no leſs convenient and advantageous than eaſy to be got at. When Men, after the Setting of the Sun, ſaw the Stars of the Sign *Aries*, aſcend the oppoſite Horizon, and diſtant from the Sun by one Half of the Heaven, they then knew that the Sun was under the Sign *Libra*, which being the ſeventh of the celeſtial Signs, was diſtant from the firſt by one whole Half of the Zodiac. When at the Approach of Day they ſaw in the Middle of the Heaven, and at an equal Diſtance from Eaſt and Weſt, the fineſt Star of the Sign *Leo*, they eaſily underſtood, that the Sun, then ready to riſe, was at the Diſtance of three Signs from *Leo*, and removed towards the Eaſt one quarter Part of it's Circle. Thus, without ſeeing the Stars, which the Sun drown'd by it's Brightneſs as he came under them, they ſaid with a perfect Aſſurance, the Sun is now in *Taurus*; two Months hence we ſhall have the ſhorteſt Day. They could, on ſight of a ſingle Conſtellation, placed in the Eaſtern or Middle or Weſtern Part of the Heaven, immediately ſay where the Sun was, how far the Year was advanced, and what kind of Work it was fit they ſhould buſy themſelves about. After this Manner Shepherds and Farmers ſtill regulate their Works; and if we now are ignorant of the Names of the Stars, if we are not able to determine the Diſtance between one Conſtellation ſhewn us, and the actual Place of the Sun, it is becauſe we can read and write. The firſt Men peruſed the Heavens for want of writing; and it is on account of the Conveniency of writing, that the Generality of Men now diſpenſe with looking among the Stars for the Knowledge of the Operation and the Order of the Year. But writing itſelf, that ſo uſeful Invention, is one of the Products of Aſtronomy; and it may be eaſily ſhewn you alſo, that the Names given the twelve celeſtial Signs, gave Birth to the Invention both of Painting and Writing. This Hiſtory promiſes you a very agreeable Novelty, and it will continue to inform you of the Helps, for which we are indebted to the Study of Nature.

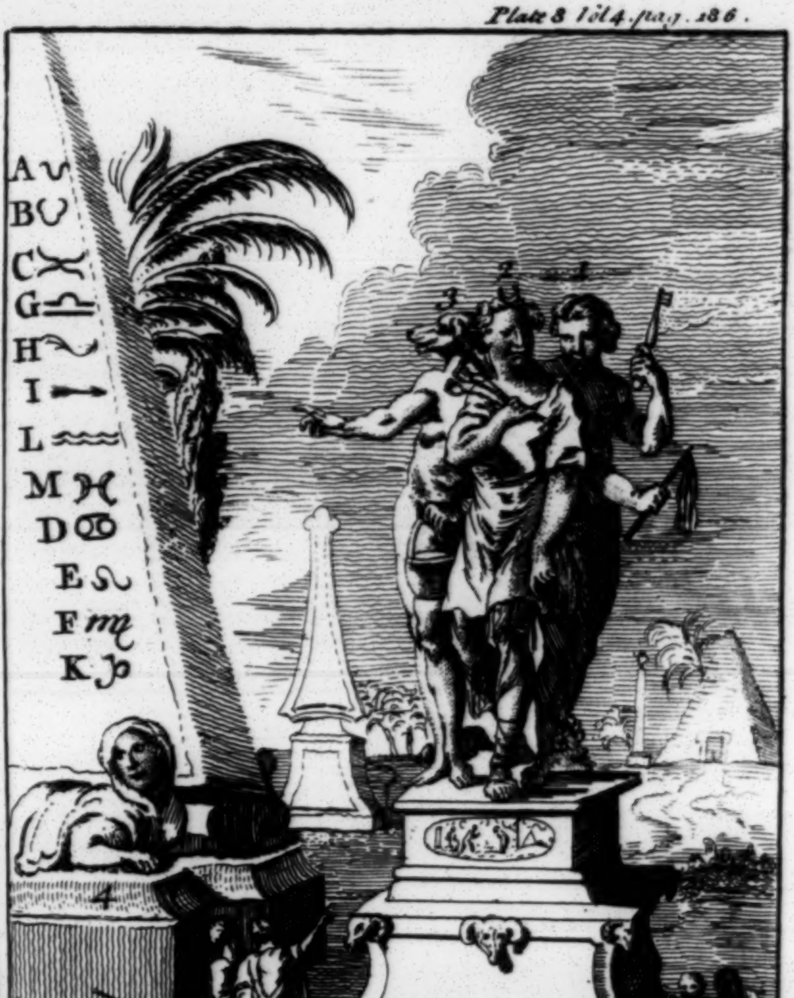
It ſeems that Painting was known before Writing. Aſtronomy gave Birth to Painting. They both afterwards concur'd to cauſe the Art of Writing to be invented.

The Invention of Writing.

Eight of the Figures of the Zodiac have ſo evident an Analogy with the Animals or Objects of which they have the Names, that we cannot doubt, but that they are Pictures of them. The firſt A is a Sketch of the Horns of the Ram (*Aries*). The ſecond B viſibly is the fore-part of a Bull's Head. The third C is the Union of the two Heads of Kids. The ſeventh G is nothing elſe than the Beam of a Balance. The eight H is a ſlight Sketch of the Paws, the long Tail and the Sting of a Scorpion. The ninth I is the Arrow itſelf of the Archer or Hunter, whoſe Name it goes by. The eleventh L is the Expreſſion of a Current of Water; and the twelfth M that of two Fiſhes ſet Back to Back. Theſe other four D, E, F, K, reſſembling their reſpective Objects at firſt, have been alter'd in Time, for the Convenience of Abbreviation.

I dare not preſume to affirm, that theſe current Abbreviations are of the greateſt Antiquity. But the entire Figures of the celeſtial Signs being frequently found in the Monuments of the *Egyptians*, which are known to be of a Date but little diſtant from that of the Flood, we may thence judge of the Antiquity of the Zodiac, and of the Repreſentation, which was made of it for regulating the People. This Painting was the Foundation of the Art of Writing; ſince by ſhewing ſomthing to the Eye, it gave the Miud ſomething more to underſtand. This convenient Invention got grounds by degrees. *Thot*, the *Egyptian*, imagined ſome other Symbols, relative to the Wants and the peculiar Production of *Egypt*. For Inſtance, the Symbol of the Sun, which regulates the Courſe of whole Nature, was a Man arm'd with a Whip like a Coachman, or adorn'd with a Scepter like a King and that Figure was called *Oſiris* *, that is the Leader, the Inſpector, or the King. The Earth, which produces every Thing, and inceſſantly varies its Productions, was repreſented under the Symbol of a teeming Woman, whoſe Attributes were varied according to the Feaſts or Works they had a Mind to proclaim; and this Figure's Name was *Iſis*, that is, the Woman, or the Queen. The Creſcent, which was the Mark of the *Neomenia*, or the Aſſembly of the People, being put on her Head with ſuch or ſuch another Attribute, might mark out the Aſſembly of this or that Seaſon. The bright Star of the Dog, which begins to appear in the Morning before Dawn, and to diſengage itſelf from the Rays of the Sun, when it enters the Sign *Leo*, was the infallible Sign of the Time when the *Nile* was to overflow. It warn'd the *Egyptians* to haſten their retiring to higher Grounds, and lay in their ſtores of Victuals, and to avoid all ſurprize. It did for them the Part of the Animal, who warns his Maſter of the approach of Thieves. Wherefore it was repreſented under the Figure of a Dog, or of an human, Body, having a Dogs Head, with Wings on it's Feet, and a Kettle on the Arm. The People might eaſily underſtand this Language. In order to point out to them the Repoſe and State of Inaction they would be in, durin their Retreat, and the Inundation, which was to laſt almoſt all the Time that the Sun ſhould be under the Signs *Leo* and *Virgo*; they placed on the Edges of Terraces the Figure of the Sphinx, made up of a female Face, and the Body of a Lion couching and unactive.

Plutarch, *de Iſid.* & *Oſir.*



1. Osiris with a Key, a Whip, and a Crab upon his Foot; the public Sign of the beginning of the Solar year under Cancer. 2. Isis, or the Public Sign of the Neomenia. 3 Anubis, or the public Sign of the rising of the Dog-star, concurring with the beginning of the year. 4. The Sphinx, or the Mark of the duration of the inundation.

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active. The great Concern of the *Egyptians* was to know the Return and Duration of the *Eteſian* Wind, which collected the Vapours in *Æthiopia*, and cauſed the Inundation, by blowing from North to South towards the End of the Spring*. Their next Concern was to know the Return of the South Wind, which help'd on the flowing of the Waters towards the *Mediterranean*. But how ſhould they repreſent the Wind? In order to this, they choſe the Figure of a Bird †. The Hawk, which ſpreads his Wings, looking to the South, to renew his Feathers at the Return of the Heats, was made the Symbol of the *Eteſian* Wind, which blows from North to South; and the Whoop, which comes from *Æthiopia*, to find Worms in the Slime after the Draining of the Waters of the *Nile*, was made the Symbol of the Winds proper to help on the Efflux of the Waters. Theſe few Examples may give you a Notion of the ſymbolical Writing of the *Egyptians*. It is peculiar to them, from the extenſive Uſe they made of it. But the Invention of the Zodiac, which occaſion'd it, is more antient than the *Egyptian* Colony, and comes from the Plains of *Shinar*. For, had the *Egyptians* been the firſt Authors of the Names of the celeſtial Signs, they would not have placed the Figure of a young gleaning Maid after the Sign *Leo*, for a Mark of the Harveſt, which is indeed finiſh'd at that Time in other Places, but is ſtill at a very great Diſtance in *Egypt*. All then being under Water, they are obliged to defer ſowing till a good way in *November*, that they may in *March* or *April* get in their Corn, which is thus but four Months a ripening.

This ſymbolical Writing, the firſt Product of Aſtronomy, was made uſe of, to inform the People of all neceſſary Truths, Advices, and Works. But it became troubleſome, by the Multiplicity of the Figures and of the Attributes, which increaſed in Proportion to the Number of the Objects; an Inconvenience ſtill found in the *Chineſe* Writing, where each individual Thing has its peculiar Symbol. A happy Genius, whoſe Name has not been deliver'd down to us by Hiſtory, and which, as he lived before *Moſes*, is very different from *Cadmus*, to whom the *Greeks* aſcribe the Honour of this Invention, obſerved, that the Sounds and the Articulations of the Voice, with which we may expreſs every Thing, are not very many; and bethought himſelf of repreſenting theſe Sounds and Articulations by ſo many Characters, which are not above four and twenty.

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* Plutarch. de Iſid. & Oſir.

† Job. xxxix. 29.

That Writing, which, by repreſenting the Sounds of the Voice, is able to expreſs all the Thoughts and Objects, which we uſed to ſignify by theſe Sounds, appear'd ſo very plain and fruitful, that it made its immediate Way. It ſpread every where; it became the current Writing, and cauſed the Symbolical, the Uſe of which was gradually loſt among Men, to be neglected; ſo that in Time the very Meaning thereof was entirely forgot.

But many Symbols, conſecrated by antient Cuſtom, being very often exhibited to the View of the People in public Monuments, in Places of religious Meetings, and in the Ceremonials of Feaſts, which never alter'd, the People ſtupidly fix'd their whole Attention on the Figures they ſaw; and going no farther than the mere Symbol itſelf, of Courſe overlook'd the Senſe thereof. They took the Man dreſs'd like a King, for a Man that ruled the Heaven, or that reign'd in the Sun. They took the ſymbolical Woman for a real one, and the figurative Animals for Animals themſelves. They in a confuſed Manner knew that theſe Figures related to the Sun, the Winds, the Seaſons, and the ſeveral Parts of the Heaven. But in order to acount for all theſe Repreſentations of Men, of Women, of the ſeveral Habits and Inſtruments, they hiſtorically interpreted the whole. They took theſe Emblems for ſo many Monuments of what had happen'd to the Founder of the *Egyptian* Colony. The King, or *Oſiris*, which ſignify'd the Sun, was miſtaken for *Cham* or *Ammon*, their common Father; and the latter lodged in the Sun, was miſtaken for a favourable and beneficial Power, which after his Death, and his Tranſportation into the Sun, watch'd over *Egypt*, and had a moſt particular Affection for it. He was call'd *God*, *Jove*, *the God Ammon*, *the King*, *the Governor of the World*. Thus the Notions of a God, of the Sun, and of a dead Man, were confounded with one another. *Iſis*, with all her Attributes, was taken for *Ammon*'s Wife, and became the

Queen of Heaven. The other celeſtial Signs ſerved them as Attendants. Such is the Origin of the King, Queen, and Hoſt of Heaven, the Worſhip of which is ſo often given as a Reproach to the *Iſraelites* in Scripture. But as the *Egyptians* could not clear antient Hiſtory by the Attributes of theſe Figures, which had certainly no Manner of Relation thereto, they diviſed Facts and Hiſtories, to account for the Attributes themſelves. We, as you ſee, are touching on the Origin of Idolatry; and it would be an eaſy Matter to ſhew you, that the Feaſts of the *Egyptians* thus perverted, but every where admired on Account of their Pomp, and of the Affluence and Plenty *Egypt* then enjoy'd, were communicated from one Country to the next, and gave Birth to Fables, Metamorphoſes, and the Multiplicity of Gods, by the bare Change of Names, or of Decorations. You will again find the *Oſiris* and *Iſis* of the *Egyptians*, in the *Adonis* and *Venus* of the *Phenicians*, in the *Cybele* and *Atys* of the *Phrygians*. Each Nation afterwards imagined they had found their deified Founders in theſe Symbols, which vary'd from one Country to another; which gave Birth to that monſtrous and inconſiſtent Medley of Truths and Extravagances, which are found in the Fables of Paganiſm. You already gueſs, that the Entrance of *Oſiris* and *Iſis* in *Aries*, *Taurus*, and other celeſtial Animals, gave Birth to the Worſhip of Animals in *Egypt*, and to the pitiful Doctrine of the *Metempſichoſis*. When they had a mind to ſet out on a Journey, or to begin to plow, *&c.* the Cuſtom was firſt to conſult the Birds. You preſently underſtand, that by this is meant conſulting the Winds. Theſe ſymbolical Birds being gradually taken for real ones, which had the Power of foretelling future Events, the Birds themſelves were moſt earneſtly and religiouſly conſulted. Judge what Anſwers could be had from them. The whole antient Ritual, which was ſymbolical, having been literally taken, the World was fill'd with Errors, Idolatry, and Superſtitions. I here begin to enter upon a Subject infinitely engaging, and offer you the Means of accounting in the plaineſt Manner, why Idolatry, Superſtitions, and Fables, have always united three particular Characters; the one, of being related to the Heaven and the Stars; the other, of having many Relations with Names and Facts, drawn partly from ſacred, partly from profane Hiſtory; and the third, of every where offering us a few Remains of Truths, blended with a horrid Mixture of Notions infinitely abſurd. But we could never engage in the Origin of Idolatry, and of the Extravagance of Divinations, or of Aſtrology, without deviating from the Spectacle of Nature, and from the Hiſtory of the Study made of it. Let us go on with conſidering its Progreſs. I ſhall perhaps try, in a ſelect Treatiſe, to ſatisfy you concerning the Origin of the poetical Heaven, on the Falſeneſs of the Chaos, which has ſeduced Philoſophers as well as Poets; and finally, on the perfect Agreement of Experience with the Phyſics of *Moſes* *.

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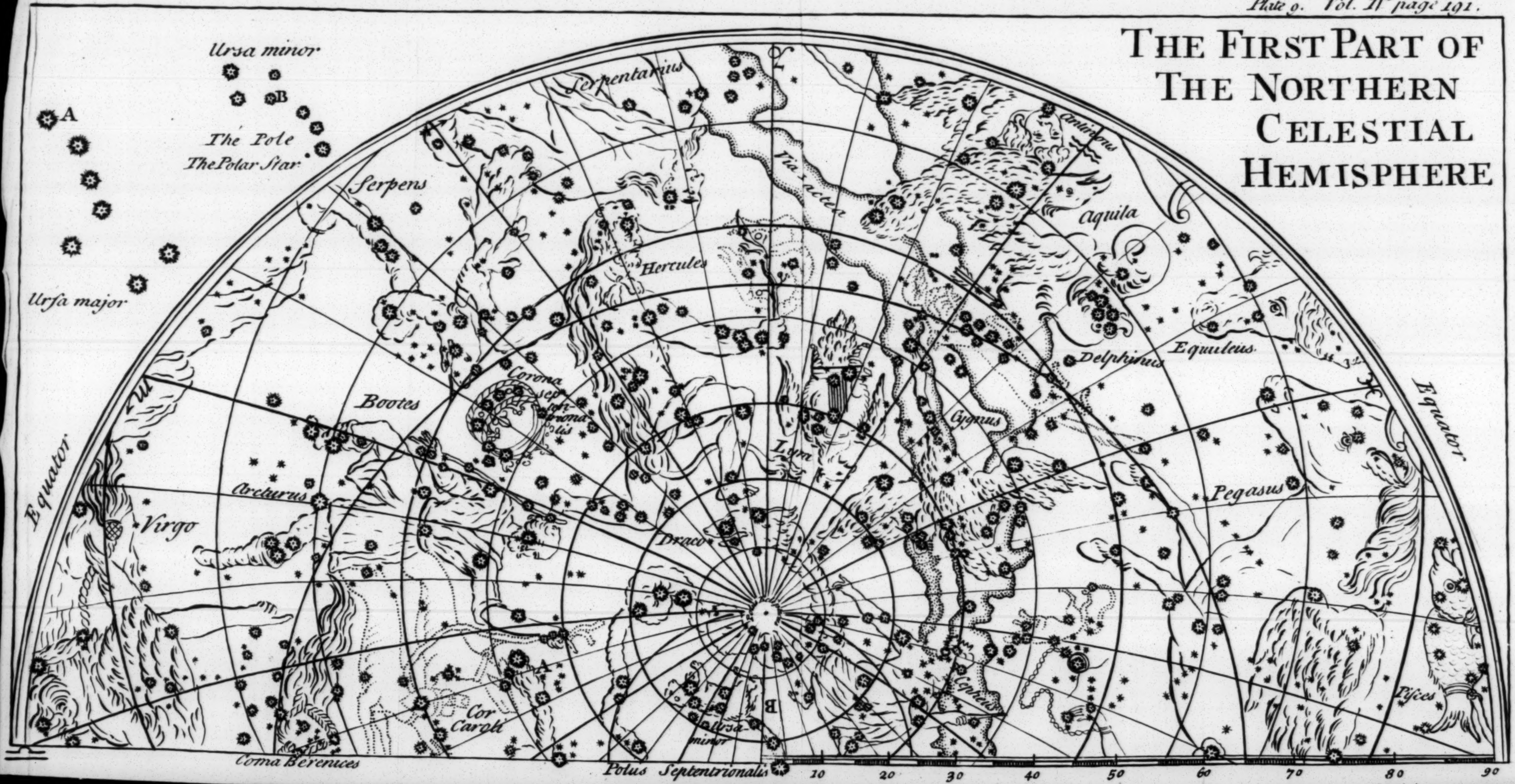
* You will find this Subject treated at large in a Book intitled, The Hiſtory of Heaven.

THE FIRST PART OF THE NORTHERN CELESTIAL HEMISPHERE



THE DISCOVERY OF THE POLAR STAR.

The Voyages *of the* ANTIENTS.

DIALOGUE II.

WHEN I gave you the Hiſtory of the firſt Informations given Mankind about Aſtronomy, Phyſics, and Husbandry, I could not avoid, my dear Chevalier, at the ſame Time giving you a Hint of the Source and Beginning of the enormous Miſtakes, which the forgetting of theſe Informations has occaſion'd. Without tracing Idolatry through all its Branches, I think I have ſhewn you, by a competent Number of Circumſtances, the Concurrence of which cannot be an Effect of Chance, that the Figures of Men, Women, and Animals, which were delineated in antient Writing, and which were relating to the Feaſts and Operations of the Year, have, through Ignorance, been changed into ſo many celeſtial, terreſtrial, and infernal Powers. The little I told you of this is ſufficient to make you obſerve in the Variety of the Symbolical Figures, and of the repreſentative Ceremonies thereto annex'd, the Origin and Explanation of the monſtrous Deities, whom our Forefathers adored, and of the no leſs monſtrous Opinions, which from Age to Age, even to our own, have enſlaved the Minds, weaken'd

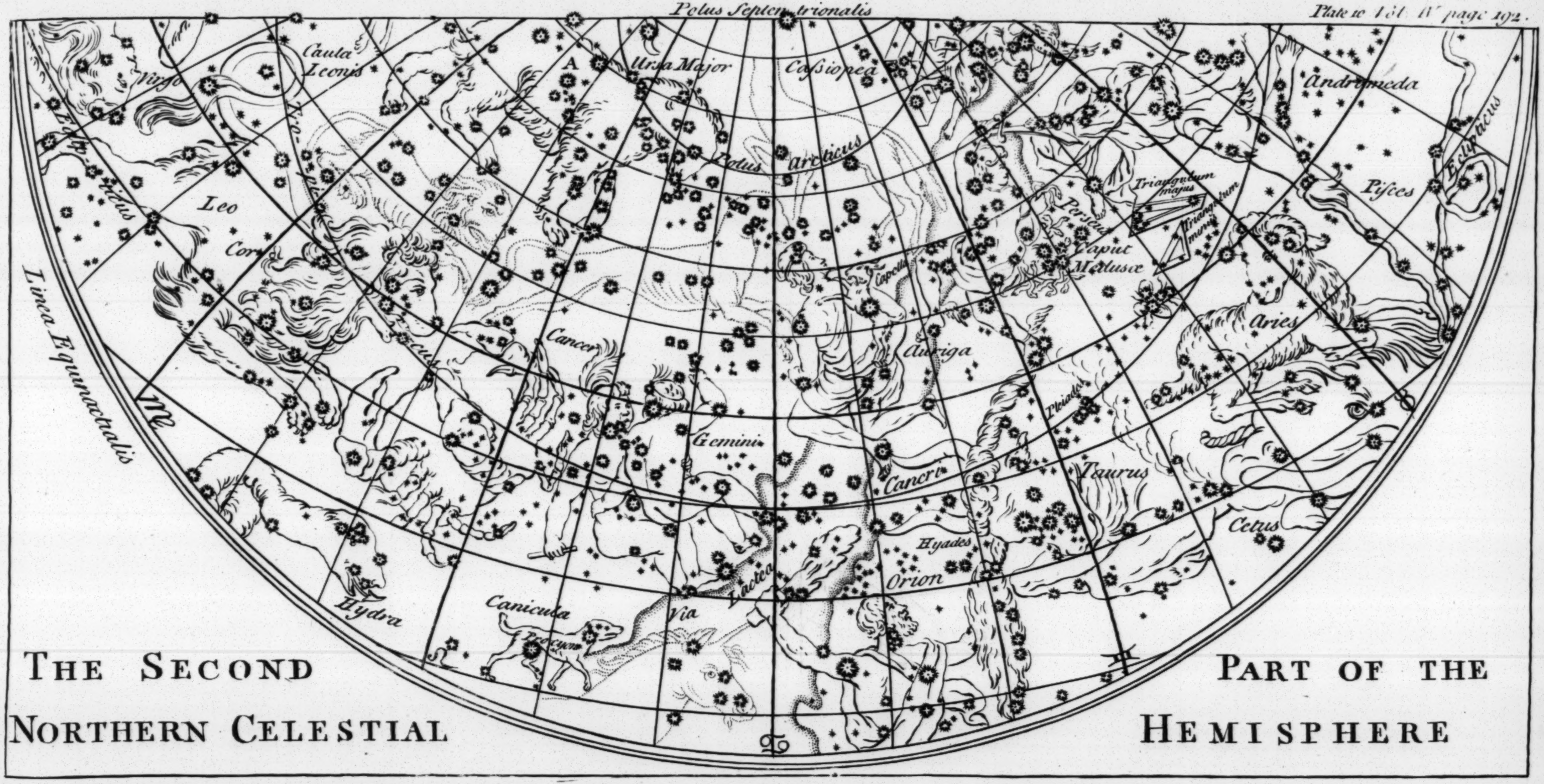
Piety, and led the Learned aſtray in the Study of Nature. But though the greateſt Philoſophers have diſhonour'd themſelves, either by their Affection for Idolatry, or by their Prejudice in Favour of judicial Aſtrology, or even by their Irreligion; we have ſufficiently expoſed their Failings. Let us now turn our Eyes from theſe, to ſee the Good only that was in them, and the Legacies they have left us. From the Hiſtory of their Miſtakes, on which I ſhall in another Place, and more at Leiſure, be very particular, let us return to that of their Induſtry.

The Diſcovery of the two Urſæ, and of the Polar Star.

The Exigences of Husbandry, which was no longer the ſame as before the Flood, firſt diverted the Attention of Men to the new Courſe of the Sun, and made them invent the Zodiac, Writing, ſurveying of Land, hunting of wild Beaſts, and the Method of regulating the public Order of their Operations and Feaſts. The Exigencies of Trade, of Tranſportations, and of Navigation, cauſed Men afterwards to find out in the Heaven, the Situation and Motions of both the Bears. They ſaw moſt of the Stars aſcending the Horizon as well as the Sun, then riſing up obliquely, and, like him, approach the Place where he appears at Noon; then to draw towards the Weſt, and hide themſelves under the Earth. But Navigators obſerved, that there were ſome Stars, which never ſet, and which every Night in fair Weather were ſeen on that Side where the Sun never appears; or in other Words, on their left Side, when their Eyes were turn'd towards the Eaſt. They did not long heſitate on the Uſe they might make of theſe Stars, which always ſhew'd them the ſame Side of the World; and when foul Weather put them out of their Way, and turn'd the Head of their Veſſel towards theſe Stars, which they had before on their Side, they naturally ſteer'd ſo as to place the Ship in its firſt Situation, with regard to theſe conſtant Stars. The Immobility of that Part of the Heaven became the *Rule* and the *Security* of Navigators.

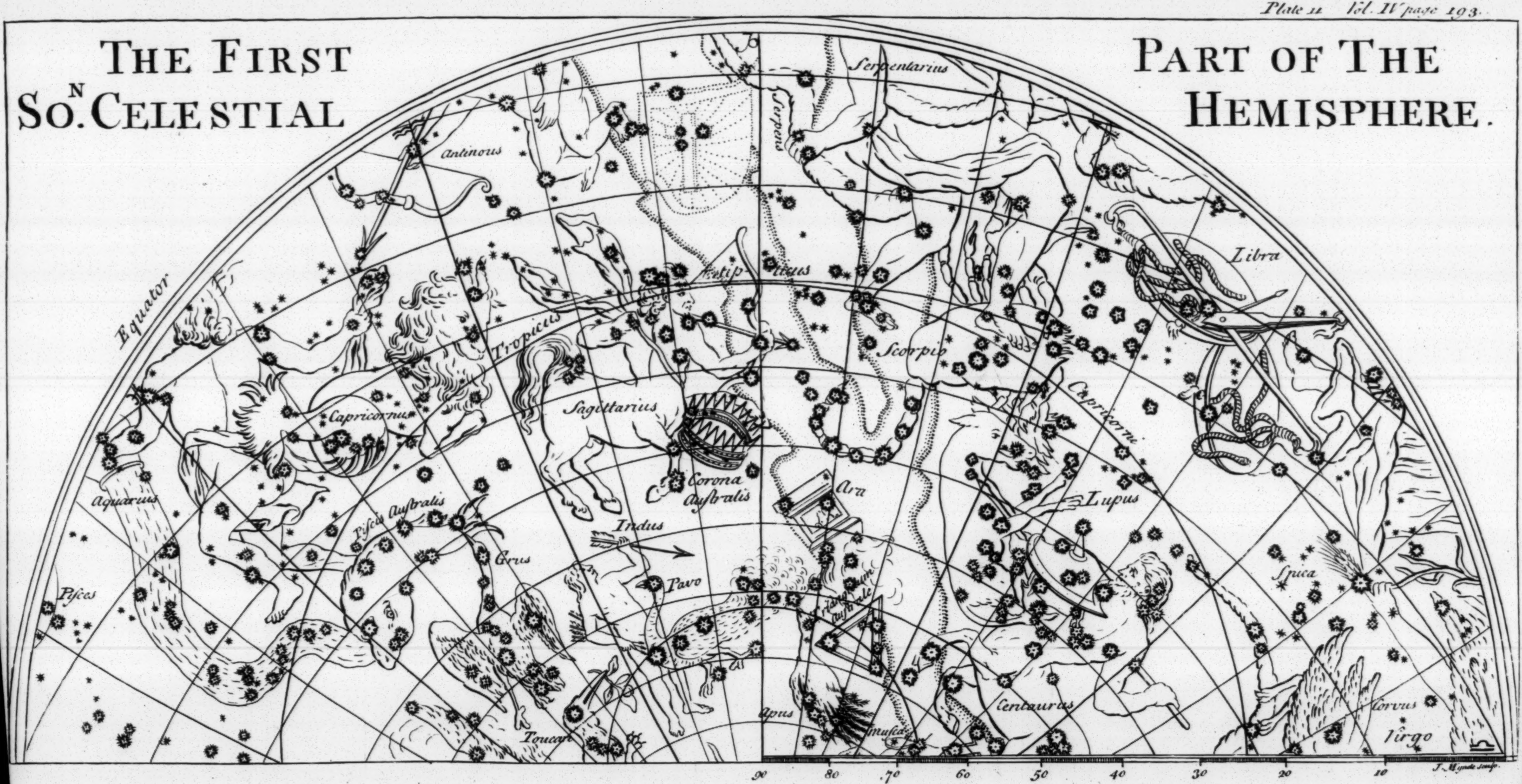
The Origin of their Names.

Theſe Stars, by appearing again, indicated to them their Courſe, and as it were ſpoke to them. This important Singularity made them to make an exact Study of the Conſtellations of that Part of the Heaven, which it was moſt



THE SECOND PART OF THE NORTHERN CELESTIAL HEMISPHERE

THE FIRST PART OF THE SO^N. CELESTIAL HEMISPHERE.



eaſy to diſcern. None appeared on that Side more remarkable, than that which is compoſed of ſeveral Stars, among which they reckon ſeven of the brighteſt ſort, and which takes up a pretty large Space. The People who ſaw this Conſtellation ſometimes above, ſometimes below, ſometimes on one Side, and always beginning the ſame Revolution again, named it the *Wheel*, or the *Chariot* [a]: And it is becauſe the *Romans* called *Terio* the heavy Carts they uſed to preſs the Ears of Corn withal [b], and to clear them of the Corn; that they gave the ſeven fineſt Stars of that Conſtellation the Name of *Septentrio*. But the *Phœnician* Pilots, which had their Eyes inceſſantly fixed thereon to receive its Inſtructions, with greater Reaſon called it ſometimes *Parraſis* [c], the *Inſtruction*, the *Indication*, the *Rule*, ſometimes *Calitſa* [d] or *Calliſto*, that is, the Deliverance, the Safety of Sailors, but much more commonly *Dobebé*, or *Doubé* [e], a Name which Aſtronomers give it ſtill, and which ſignifies the *ſpeaking* Conſtellation, the Conſtellation *that gives Advices*.

By ill Fortune the ſelf-ſame Word *Doubé* ſignified alſo a She-Bear in the Language of the *Phœnicians*, who communicated it to the *Greeks* only in that Senſe, quite foreign to the Figure or the Uſes of the Conſtellation. It had however borrowed therefrom until now, the Name it actually goes by. You have ſeen the pretty Stories which *Ovid* and other Poets have publiſhed about that ſame She-Bear. They make her a Maid called *Calliſto*. They ſuppoſe her to be born at *Parraſa*, an *Arcadian* City, and are fully acquainted with both her Genealogy and Adventures. *Jupiter* being angry, on ſeeing that the Jealouſy of *Juno* had changed *Calliſto* into a *She-Bear*, pretends to have at leaſt the Satisfaction of having lodged her in Heaven. But *Juno* takes Care to oblige her to keep in a Place of the Heaven, whence ſhe can never deſcend below the Horizon, as do the reſt, to cool herſelf in the Waters of the Ocean[*]; that ſo by this Situation her Conduct may always be obſerved. From this Inſtance, you may judge of the Origin of Hundreds of other Metamorphoſes, which owe their Birth to a Word that had a double Meaning. But let us leave the Heaven of Poets, and return to that of Obſervers.

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[a] Ἄρκτον θ᾽ ἣν καὶ ἄμαξαν ἐπίκλησιν καλέουσι. Iliad. Σ.

[b] *Terendis frugibus.*

[c] פרשה *Parrſha* Indication, from פרש *Paraſh* to ſhew, to clear, to teach. Whence 'tis like the Name *Phariſee*, that is, *Doctor*, came.

[d] חליצה *Calitſa* Deliverance, from חלץ *Calats*, to ſave, to deliver.

[e] From רבב *Dabab* to ſpeak, comes *Dobebé* or *Doubé*, ſhe that ſpeaks.

After the Obſervation of the She-Bear, they ſoon remarked, that, as it filled a great Space in the Heaven, and made a very large Revolution, it expoſed Pilots to the Danger of deviating conſiderably from their true Courſe, if, towards the End of the Night, they ſhould fancy the *Urſa* to be in the ſame Situation as it was in the beginning of the Night. The Difference of the latter from the former Situation, is, it may be, a quarter Part of the Horizon or more. It obliged Sailors to go by the Eſtimation they made of that Difference, which might occaſion Miſtakes. *Urſa Minor.* They then obſerved another Conſtellation, leſs bright indeed, but almoſt of the ſame Form of the firſt, filling a leſs Space, and varying its Situation not much. By the Compariſon of this with the other, they call it the little She-Bear. But the three Stars, which make up the Tail of this, being turned up in a ſort of curve Line, and imitating a Dog's Tail rather than that of a Bear, that Part of the leaſt of the two Conſtellations, borrowed therefrom the Name of *Cynoſure*[†]. But Sailors made it their chief Study, to obſerve the laſt Star of the Tail of *Urſa Minor*: Becauſe being very little diſtant from the Pole, that is, from the Point on which the whole Heaven ſeems to revolve, it deſcribes round it ſo ſmall a Circle, that it hardly is perceptible; ſo that it always is ſeen towards the ſame Point of the Heaven. We, for this Reaſon, call it the *Polar Star* and thoſe

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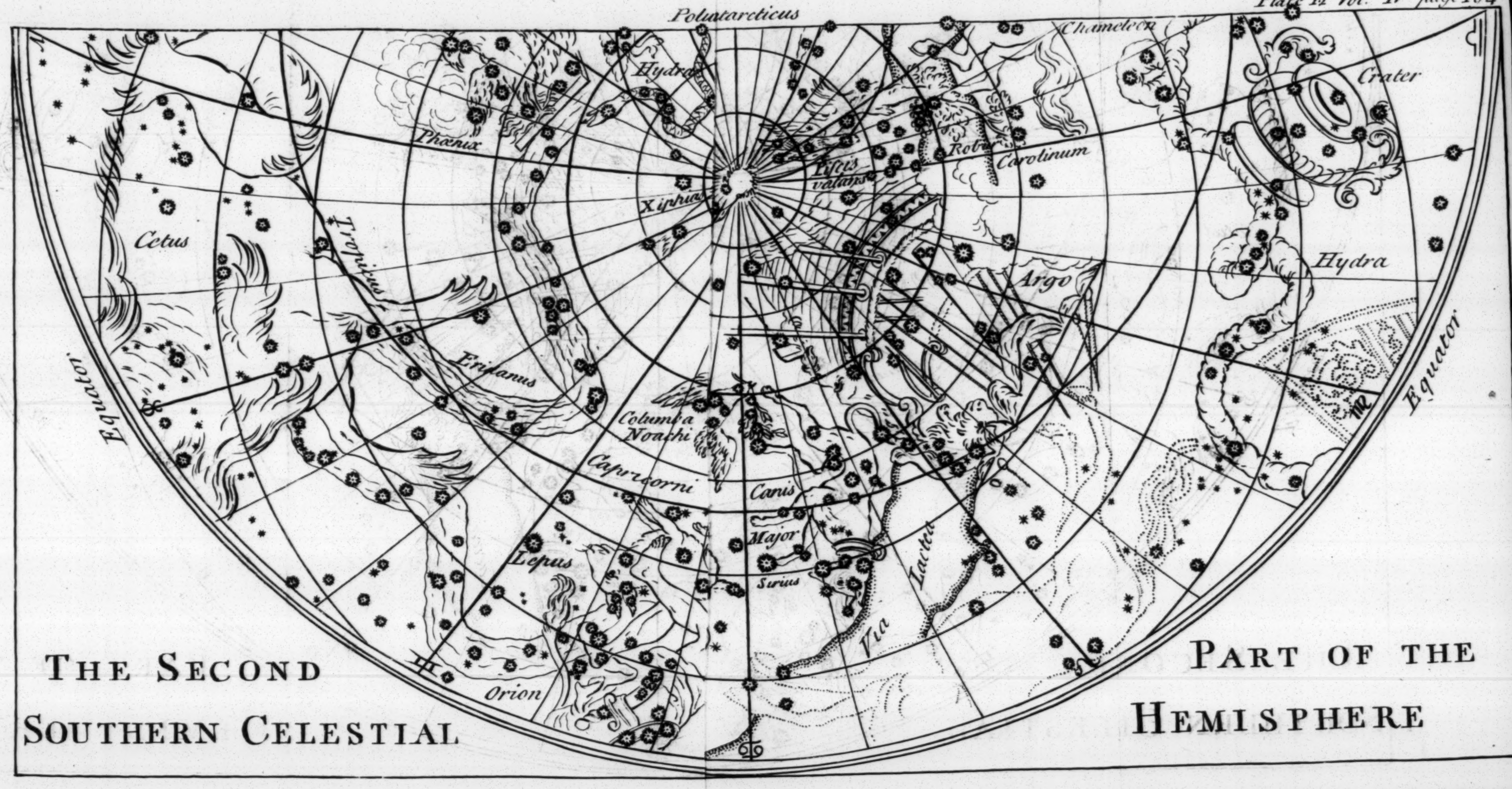
[*] --- Οἴηδ' ἄμμορός ἐςι λοετρῶν ὠκεανοῖο. Ibid.

[†] Κυνὸς οὐρὰ, the Tail of the Dog. See *Didymus* on the 485th Verſe of the 18th Book of the *Iliad*. Ἡ μίκρα (ἄρκτος) ἡ κυνόσουρα καλουμένη διὰ τὸ ὡς κυνὸς ἔχειν ἀνακυκλουμένην τὴν οὐρὰν (not ἀνακεκλασμένην, as the Edition of *Baſil* has it; which is of no Meaning at all).

that



THE SECOND PART OF THE
SOUTHERN CELESTIAL HEMISPHERE

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that ſail on the *Mediterranean*, call it *Tramontane* [a], becauſe they ſee it over thoſe Countries which are *trà Monti*, that is, on the other Side the *Alps*.

The Knowledge of the Polar Star rendered Navigation more bold and proſperous. Before *Thales* the *Mileſian*, who had learned from the *Phœnicians* the important Uſe of this Obſervation, had communicated it to the *Greeks* of *Ionia*, and through theſe to all *Greece*, near ſix hundred Years before *Chriſt*, theſe People carried on their Commerce with the utmoſt Circumſpection and Timidity. They ſailed along the Coaſts, and not only durſt not venture far from them, but they never undertook any long Voyage. The Reader is amazed at the Alarms, Deliberations, and great Preparations of *Homer*'s Heroes, when they are to croſs the *Ægean* Sea [b]. You may have obſerved that *Virgil*, always mindful of introducing a perfect Conformity between the Adventures of his Heroe, and the Uſages of the Time in which he places him, makes him coaſt along the Shore of *Greece*, *Italy*, and *Sicily*, without leading him through the main Sea, as it was natural he ſhould. After he had brought him to the Extremity of *Italy*, he cauſes him to make the long Circuit of *Sicily*, rather than convey him to the Mouth of the *Tyber*, through the Streights of *Meſſina*; in which they at that Time were afraid of meeting with *Charybdis* and *Sylla*, which frightened no body in the Time of *Virgil*. But nothing made a greater Noiſe before the Siege of *Troy*, than the Expedition of the *Argonauts*, that is, the Paſſage of the *Propontis* [c], and of the *Pontus Euxinus* [d]. It was looked upon as a wonderful Exploit: It became the Subject of the fineſt Poems: Nay, the Gods themſelves were amazed at the Boldneſs of the Undertaking; and in order to eternize this Event, they placed in the Heaven, among the brighteſt Conſtellations, the admirable

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[a] Therefore the *French* ſay of a Man, *that he has loſt the Tramontane*, when his Affairs are diſordered, and he has no Reſource left, or any Means to unravel them. He is like a Pilot that has loſt Sight of the *Pole-Star*.

[b] See the *Odyſſ.* Book 3.

[c] Now the Sea of *Marmora*, between the Streights of the *Dardanels*, and that of *Conſtantinople*.

[d] Now the *Black Sea*.

Ship which had been able to paſs from *Jolchos*[a] to the Mouth of the *Phaſe*. This now is done by the meaneſt *Turkiſh* Barks.

While the Want of the Knowledge of the Stars, eſpecially of the Polar Star, rendered the *Greeks* ſo timorous at Sea, Navigation on the contrary was extremely improved by that Aſſiſtance among the *Phœnicians*, and had made their Territory (which was but a Border of *Syria*, of little Extent in Length, and of almoſt no Breadth at all) a moſt wealthy and renowned State. They had at that very Time Correſpondences, and even very good Eſtabliſhments in all the Coaſts of the *Mediterranean*. We find again their Colonies[b], and a Multitude of proper Names of their Tongue, in the inner Parts, and on the three Coaſts of *Sicily*. It is the ſame with the ſix other chief Iſlands of the *Mediterranean*, viz. *Sardinia*, *Corcyra*[c], *Crete*[d], *Cyprus*, *Eubœa*[e], and *Leſbos*[f]. We find again the ſame Proofs of their ſojourning, or of their frequent paſſing in the Iſlands of the ſecond Rank, ſuch as are *Lemnos*, *Chios*, *Samos*, *Naxia*, *Rhode*, *Zante*, *Cephalonia*, and the three *Baleares*[g]. They diſcovered all the ſmalleſt Iſlands, and made them known. Theſe are the *Cyclades* on the left Side of the *Archipelago*, and the *Sporades* ſcattered on the Right. The Cities of *Adrumet*, *Clypea*, *Carthage*, *Utica*, *Hippone*, and a great many others along the Coaſts of *Barbary*, are ſo many Eſtabliſhments, which the *Sidonians* and *Tyrians* made there at ſeveral Times. They had many Sea-Ports in *Spain*, eſpecially in the *Bœotica*, which is the modern *Andalouſia*. All that Country, and particularly the *Bœtis* or *Guadalquivir*, which waters it, went at that Time by the Name of *Tarſis*, or *Tarteſſe*[h]. The good Wines, the Timber, the Exquiſiteneſs of the Corn and Cattle, but above all, the Gold, the Tin, and the Silver, of which

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[a] A City of *Theſſaly* at the Bottom of the *Gulph*, where the City called the *Demetriade* was built long after.

[b] See the *Canaan* of *Samuel Bochart*.

[c] Now *Corfu*, at the Entrance of the Gulph of *Venice*.

[d] Now *Candia*, below the *Archipelago*.

[e] Now *Negropont*.

[f] Now *Metelin*.

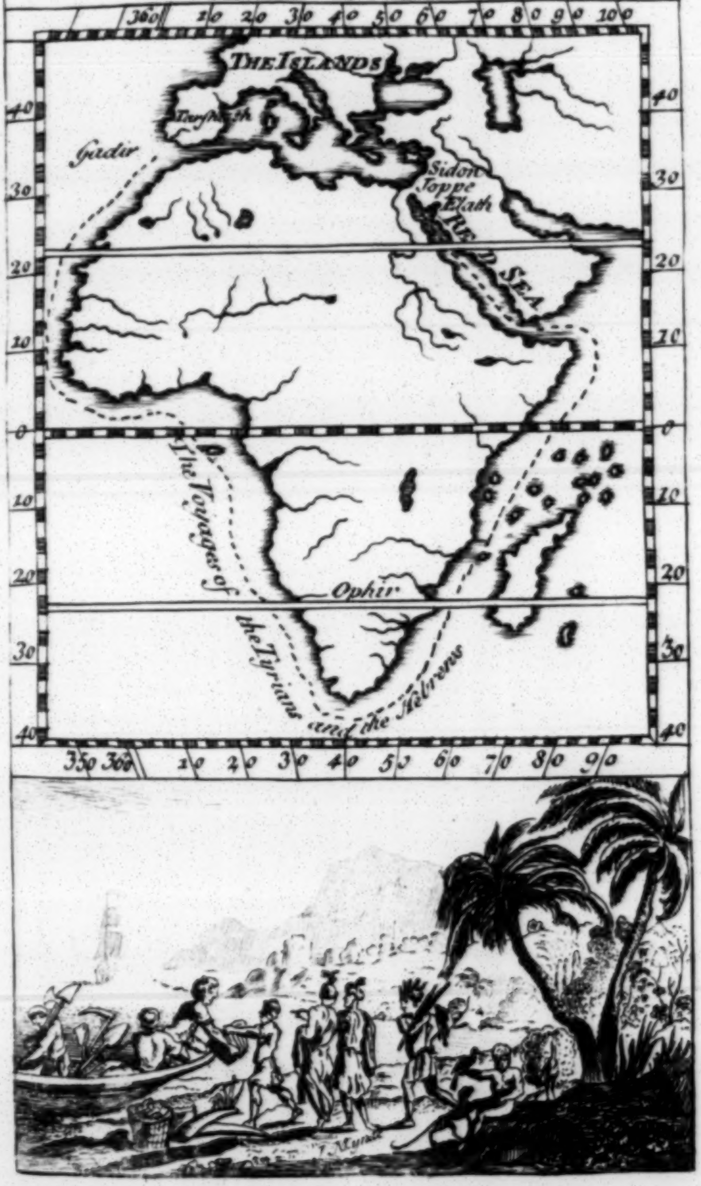
[g] Now *Majorca*, *Minorca*, and *Ivica*.

[h] See *Pauſan*, *in Eliacis ſecundis*.

there

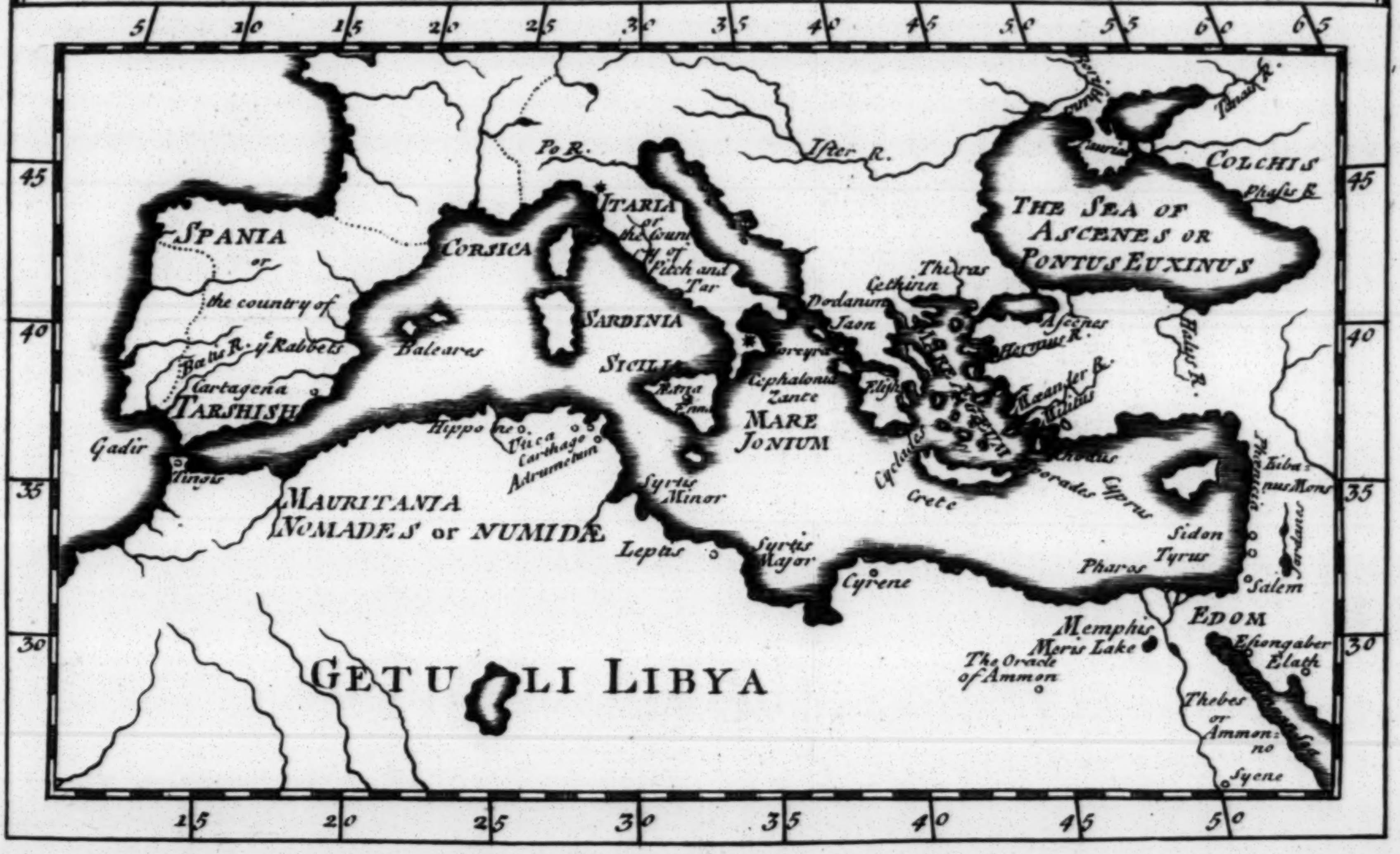
THE PORT OF OPHIR

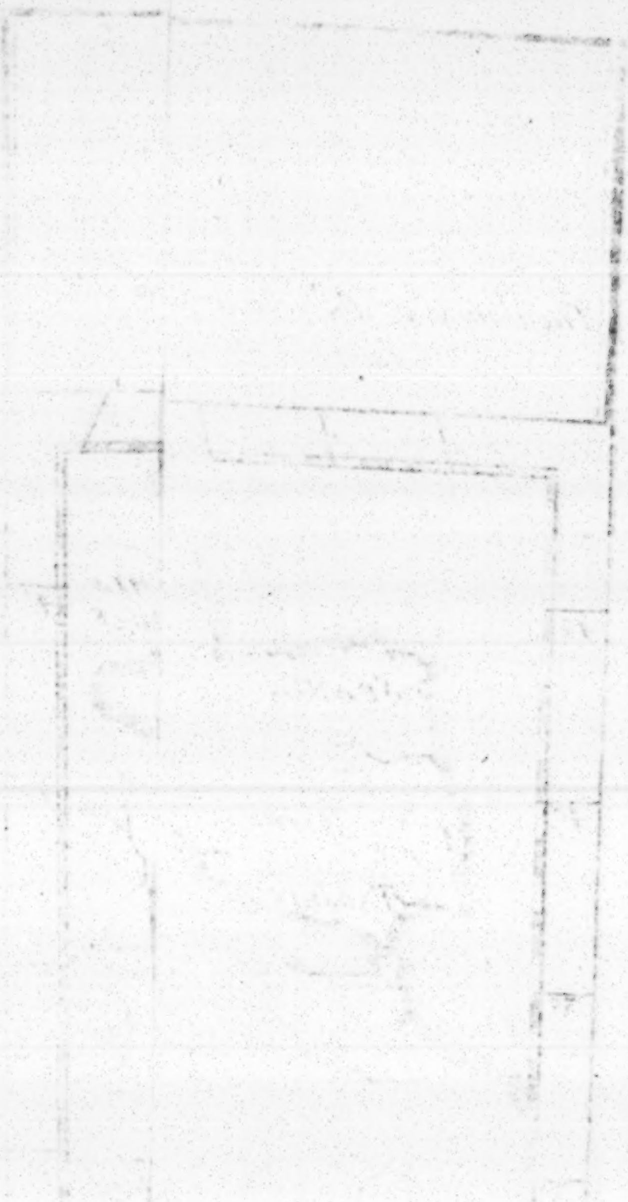
AND THE ANCIENT WAY TO TARSHISH.



THE PHENICIAN
COLONIES.

The names of the countries watered by the Mediterranean are all Significant in the Phenician language. Of this we may judge by the two words Spain and Italy.





here were very copious Mines at that Time, eſpecially towards the Source of that River[a], ſoon drew the *Phœnicians* on theſe Coaſts. But it was for a long Time the Extent of their Sea-Voyages: They went no farther. For this it is, that in Scripture the great Ships and Fleets deſigned for long Voyages, were called *the Ships of Tarſhiſh*[b]. Afterwards the *Phœnicians* took ſo much Courage as to paſs the *Streights*, and made themſelves Maſters of the Iſland, which they named *Gadir*, and is now called *Cadiz*. It was an advantageous Harbour to them, and inacceſſible to the other Nations, who had very little Skill in the Art of Sailing. It inſured them the Poſſeſſion of all the Riches they brought from *Phœnicia* or other Places to exchange them, and of thoſe they had received in return from *Bœotica*. This made them give that important Place the the Name it ſtill goes by, and which ſignifies an *Incloſure* or *Place of Refuge*.

The *Phœnicians* did not confine their Courſes to the Coaſts of the *Mediterranean*. They alſo opened themſelves the Trade of the Coaſts of *Afric* aud *Aſia*, through the *Arabian* Gulph, which was then called the *Idumean Sea*, or the *Red Sea*, from the *Idumeans*, who inhabited the Parts adjacent, and who had taken their Name, as well as their Original, from *Eſau*, who is known to have been ſurnamed the *Red-hair'd*, or *Edom*. Not that there was then any Trench or Communication through *Suez*[c], to paſs from the *Mediterranean* or the *Nile*, into the *Red Sea*. An Undertaking like this did little agree with the Simplicity of theſe Times; and if the Greedineſs of Riches had induced the *Phœnicians* to attempt it, the *Egyptian* Kings had not been afterwards reduced, when they did undertake it, to abandon the ſame, as they were, from the Impoſſibility there was of Succeſs[d]. But if the *Phœnicians*, though Inhabitants of the Coaſts of the *Mediterranean*, nevertheleſs travelled on the Ocean through the

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[a] *Strabo* quotes the following Verſe of *Steſichorus*:

Ταρτησσοῦ παρὰ πηγὰς ἀπείρονας ἀργυρορίζους.

Towards the Sources of the River *Tarteſſe*----Under which Silver Mines are found.

[b] *Pſal.* xlviii. 8. and *Iſai.* ii. 16.

[c] An *Iſthmus* that joins *Africa* with *Arabia*.

[d] *Herodot. in Melpom.*

Red Sea, it is becauſe they had in the Ports of the latter, Correſpondences, Offices, and Ships: A Privilege which always was, and ſtill is enjoyed in moſt of the Coaſts of *Aſia*, and indeed does much Honour to the Affability of the Eaſtern Nations.

It was the Pilots of *Hiram* King of *Tyre*, who about a thouſand Years before *Chriſt*, and when the *Greeks* were as yet unexperienced in the Art of Navigation, taught it the *Hebrews* with Succeſs, and were the Guides of the Fleets which *Solomon* had eſtabliſhed in the Ports of *Eloth* and *Ezion-geber* *. This wiſe Prince being, by the Conqueſts of his Father, become Maſter of *Idumea*, and of the farthermoſt Parts of the *Red Sea*, intended, indeed, to convey into his State Wealth, together with Trade: But his chief Deſign was, to baniſh Idleneſs and Beggary: In which he was imitated by his Succeſſors the Kings of *Judah*, and particularly by *Jehoſaphat*, the moſt pious and moſt judicious of them all. The happy and flouriſhing State of the *Tyrians* had taught *Solomon*, that wherever Navigation is in Requeſt, a Beggar, who has Limbs and Strength, differs nothing from a Criminal, and that there were almoſt no Criminals to be puniſhed, when a briſk and lively Marine offered them all an infallible Reſource, and eaſy Profits.

Let us now trace out our *Hebrews* in their Naval Courſes, and, if poſſible, let us find, what Parts of the Earth began to be known at that Time, by the Reſearches of Navigators. What Scripture tells us on that Head, amounts to the three following Facts: 1. That the *Hebrews* and *Tyrians* went together to *Ophir*, and in their Return from thence brought with them immenſe Sums of Gold, of precious Woods and Jewels. 2. That *Solomon*'s Fleets, under Direction of the Pilots of the King of *Tyre*, made the Voyage of *Tarſhiſh*, the Returns of which conſiſted in Silver, Gold, Ivory, and ſome foreign Animals, *viz.* Monkeys and Peacocks. 3. That they were three Years in making the Voyage of *Tarſhiſh*.

The firſt *Ophir* ſpoken of in the Scripture †, was perhaps in the *Fortunate Arabia*, or *Arabia Felix*. *Job* and his

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* 1 *Kings* ix. 26. 2 *Chron.* viii.

† *Geneſ.* x. 29. *Job* xxii. 24.

Friend *Eliphas*, ſeem to have known the Brooks of *Ophir*, only becauſe they were famous in *Arabia*, their common Country, by the Gold Sand they left in their Paſſage. The Name *Ophir*, already become famous, when they ſpake of the Gold Sand which the Torrents left on their Shores, was afterwards given to that Coaſt of *Africa* on which *Solomon*'s Fleets, or the *Tyrians*, found the greateſt Quantity of it. It has ſtill the ſame Name and the ſame Trade. The Names of *Sophir* and *Sophira*, by which the *Greek* Tranſlation and *Origen* * rendered the Name *Ophir*, very likely is that Coaſt which they call the Kingdom of *Sophara*. The *Portugueſe* ſoften the Pronunciation of it, and call it *Sophala*. They ſtill make there a conſiderable Trade of that precious Duſt which the Torrents ſcatter on the Coaſts, after having waſhed them from the Mines which are in Plenty in that Country, eſpecially in the Mountains of *Manica*, whence the River *Sophara* comes down.

The *Hebrews*, who had no convenient Sea-Ports in the *Mediterranean*, and would have been glad to have had a Share in the rich Trade of *Tarſhiſh*, were told by the *Phœnicians*, that by keeping cloſe to the Coaſt they would at laſt reach the Streights of *Cadiz*, and that there were immenſe Profits to be made in the Way, by exchanging ſome Tools of no Value, for Commodities of Conſequence. Thus, with their Guides, they paſſed from the Country of *Sephala*, as far as the *Southern Promontory* †, which was long after found again by the *Portugueſe*; and purſuing their Courſe from Coaſt to Coaſt, they kept cloſe to the Weſtern Shore, going up again Northward, and at laſt were carried to *Spain*, whence they returned not till the third Year. They began again the ſame Voyage every three Years, and with great Profits traded in *Spain*, and all along the Coaſts of *Africa*, as they went backwards and forwards.

Several learned Men place *Tarſhiſh* and *Ophir* in the Iſland *Ceylon*, or in the *Peninſula* of *Indus*. But our Navigators, by coaſting along the Shores, as they then did, might a few Months after have reached the Cape which terminates the *Peninſula* of *Indus*. Beſides, it is known by unqueſtionable Proofs, that the Country of *Tarſhiſh* was the *Bœotica*, or *Spain* in general; and *Jonah* would never have embarked at the Port of *Joppa* in the *Mediterranean* Sea, to take his Flight to *Tarſhiſh* towards the Weſt, if that Country had been in the Eaſtern Ocean. We then may judge by this, that the *Hebrews* and the *Phœnicians* went round the Continent of *Africa*, to join the Trade of all its Coaſts to that of *Bœotica*. The Proof of this is found in the Time of three Years, which they employed in getting back again into the Port of *Eloth*; and this Proof is ſtill ſupported by the Nature of the Commodities they brought with them. Theſe were Metals, which they had drawn from *Spain* and *Ophir*; Ivory, which they fetched from the Coaſt of the Teeth, where Elephants are more common than in any other Place; Monkeys and Peacocks, all Animals eaſy to be found on the Coaſts of *Africa*; and finally, precious Woods and Jewels. They might find on the Coaſts of *Africa*, a great Quantity of yellow Amber, of red Coral, and of other Colours, of very fine Jaſper, of which they ſtill carry on the Trade in the Kingdom of *Benin*, and ſeveral other precious Stones, which are found in the inner Part of the Country. In their Return, they might, without any Coſt, cut and ſhape the fineſt ſorts of Ebony, and other Woods uſed for inlaid Works, in the Foreſts of *Madagaſcar* and *Meſambique*, which are ſtill full of them on the Eaſtern Coaſt. They alſo found ſome other precious Woods, by touching on the Coaſts of the *Fortunate Arabia*, after they had paſſed the Streights of *Babelmandel*, which is the Entrance of the *Red Sea*.

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* In *Job* xxii. 24. *Origen* has a Suſpicion, that *Sophira* is in *Africa*.

† The *Cape Good Hope*.

This Commerce was afterwards interrupted, and that way abandoned: Not on account of the Failure of the Mines of *Andalouſia*, which were not exhauſted till the *Romans* had it; but by the weakening of the *Jews* and *Tyrians*, whoſe Trade and Commerce the Kings of *Babylon* endeavoured to ruin, before they undertook to deſtroy their Cities. However, though the Conqueſts of theſe ambitious Monarchs, by including *Idumea* and all the Ports of the *Red Sea*, had ſunk the Commerce of *Tarſhiſh*, that is, the Voyage of *Cadiz* by the long Circuit of *Africa*, they did not preſently loſe the Remembrance of that Courſe: They knew it very well at the Court of *Necao*, who reigned in *Egypt* ſix hundred Years before *Chriſt*. That Prince, who had a mind to reſtore the ancient Splendor of his Kingdom, with great Reaſon thought he could never ſucceed in it, otherwiſe than by the Re-eſtabliſhment of Navigation. In order to which he undertook the Junction of the Ocean and the *Mediterranean*, by making a Trench that was to reach from the *Nile* to the *Red Sea*. "But afterwards (theſe "are *Herodotus*'s own Words) having entirely abandoned the "Execution of that Canal, he cauſed ſome *Phœnicians* to "embark on the *Red Sea*, and ordered them to go round "*Africa*, to leave the Streights of *Hercules*, to penetrate "into the very Northern Sea, and to come again and give "him an Account of it." The *Phœnicians* (being, from the Accounts of their Fathers, perfectly well acquainted both with the Way and Method of living, without overloading themſelves with large Stores of Proviſions) ſet Sail from the *Arabian Gulph*, and advanced forward into the Southern Sea: And not being ignorant, that the Summer Rains deſtroy in the midſt of *Africa*, what has been ſowed in the Spring, "When they were in Autumn, they landed, "ſowed their Corn, and ſtaid for the Time of the Harveſt, "without leaving the Coaſts of *Libya*: They then gathered their Crop, and got to their Ships again. After two "Years Navigation, they arrived at the Pillars of *Hercules*, and paſſing the Streights, they the third Year "came back again to *Egypt* through the *Mediterranean*."

From this Recital it is plain, that nothing was then better known than the Circuit of *Africa*, and the Voyage of *Cadiz* through the *Red Sea*. The Intention of *Necao* was not to inform himſelf of the Poſſibility of that Courſe for the Good of his Commerce: In his Inſtructions to the Pilots, he ſuppoſes them to be fully acquainted with it: But his Intention is, that they ſhould do ſomething more than what was done by going through the *Red Sea* to the *Herculean Pillar*, and to try to penetrate into the Northern Sea, which very likely began to be talked of; and to inform him, whether there might be ſome uſeful Diſcovery made, or any Trade be eſtabliſhed on that Side. It was without any Neceſſity then, that the learned *Bochart*, who had ſo ingeniouſly demonſtrated the Situation of the ancient *Tarſhiſh* in *Bætica*, and near the Streights of *Cadiz*, imagines another *Tarſhiſh* in the Eaſt, thinking the Voyage round *Africa* to be then impracticable.

A little Particularity related then to King *Necao*, by his Navigators, puts the laſt Hand to the clearing of this Point of Hiſtory. At Noon the Shadow of our Bodies is always caſt towards the North, and when at that Time we look Weſtward, we have the Sun on our Left. Our *Phœnicians* on the contrary, being arrived on the Extremities of *Libya*, ſaw the Shadow of their Bodies at Noon thrown to the South. They then told the *Egyptians*, that in their going towards the Weſt, they had the Sun on their Right. The *Egyptians*, who were not by far ſo good Aſtronomers as they are ſuppoſed to have been, recounted this Fact as a wondrous Thing; and *Herodotus*, who heard of it in their Country, about a hundred Years after the Event, refuſed to give Credit to the Account that was given of it to him. But what ſurpiſed him ſo much at that Time, is the very Demonſtration of the Matter of Fact, and clears the Fact recited by the Navigators. It is now univerſally known, that the Sun keeping his ſeveral annual Situations within the Tropics, we on either Side experience two different Projections of the Shadows: Thoſe on this Side the Tropic of *Cancer*, ſee the Sun on their Left as they look to the Weſt, and their Shadow is extended towards the North. On the other Side the Tropic of *Capricorn*, it is abſolutely the Reverſe. The Shadow flies to the South, and they have the Sun on their Right as they look to the Weſt. This Particularity, ſo contrary to the Prejudices of the Ancients, and on the other hand the Return of the *Phœnicians* through the Mouth of the *Nile*, after they had begun their Voyage by the *Red Sea*, are a ſufficient Demonſtration of the Knowledge they then had of the Circuit of *Aſrica*. Theſe Voyages, which were afterwatds diſcontinued for above two thouſand Years together, and of which the *Portugueſe*, two or three Centuries ago, thought themſelves the firſt Authors, were very common in the Time of *Solomon*, and under his Succeſſors.

You ſee, Sir, that it is to the *Phœnicians* that we are beholden for the firſt Knowledge, both of the Coaſts of the Ocean, and of thoſe of the *Mediterranean*. They every where make their Way, by their conſtant Attention to the

Advices of the Polar Star, Geography begins to come to ſome Shape: Nations get out of their Darkneſs: They draw again towards each other, after the long Diſtance they had kept from one another ſince the Time of their Diſperſion. After having each of them improved the Qualities of their Land, and the Aſpect of their Heaven, they begin to communicate the Fruits of their Works, and to afford mutual Helps to each other. Men begin to form a Society; and theſe happy Novelties are the Conſequence of the Obſervation of a Star.

THE DISCOVERY OF THE ROUNDNESS OF THE EARTH.

The new Progreſs *of* GEOGRAPHY.

DIALOGUE III.

THALES was not contented with having taught the *Greeks* the Advantages reſulting to Navigation, from the Knowledge of the Polar Star: He determined for them the whole Series of the Stars under which the Sun is ſucceſſively found within the Compaſs of a Year. He afterwards, with the ſame Care, obſerved all thoſe under which the Moon paſſes within the Revolution of a Month. He ſoon found, that the Moon does not exactly place itſelf under the ſame Stars as the Sun; but that the Orbit or Series of Stars it runs under in a Month's Time, cuts the Orbit of the Sun in two Points, and deviates a little from it on either Side. He then took Notice, that the Points where theſe two Orbits cut each other, were not always the ſame from one Month to another, and that the Interſection of them happened ſometimes under one Star, ſometimes under another; but that theſe Variations, after a certain Number of Revolutions, began anew, and were again very nearly the ſame. He was, or at leaſt ought to have been, then ſenſible of the Intention of a benevolent Providence, which, by thus making the Orbit of the Moon croſs that of the Sun, had taken care that theſe great Flambeaux were not eclipſed every Fortnight, when the Moon in it's Full, or in it's Oppoſition to the Sun, ſhould be obſcured by the exact Interpoſition of the Earth in the ſame Line; or when the Moon in Conjunction, that is, placed between the Sun and the Earth, ſhould take all Light from the latter. He apprehended, that the Interſection of the Orbits, and the Variations of the Points of Section, were Means wonderfully managed and prepared, to render the exact Union of theſe three Bodies, in one and the ſame Line much more rare. But having gradually obſerved, that theſe Variations of the Moon were limited, that it began anew the ſame Changes of it's Place, and was in it's apparent Irregularities. tied up to a fixed Rule, as well as every other Part of Nature; he watched all the different Courſes of this Nightly Star, and compared a ſufficient Number of them, to make himſelf certain of the Day on which the three great Bodies ſhould be in the ſame Line, and ſcreen each other. He then came to foretel Eclipſes, and the Nations whom theſe Events uſed to terrify, took Heart again, when they heard that the ſo ſudden Darkning of theſe Stars, the Cauſe whereof they had ſo long been unacquainted with, was the neceſſary Reſult of their mutual Interpoſition, and of the wiſe Laws, according to which they revolved for the Service of Man.

The chief Benefit of the Knowledge of the Eclipſes, was not only to quiet, by the Prediction made of them, ſuch Minds as might have been frightened thereby: Geography found alſo it's Advantage in that Diſcovery, and the lunar Eclipſe more particularly ſerved to give more juſt Meaſures of the Diſtance of one Country to another. At the Approach of that Eclipſe, two Obſervers being placed, one at *Miletum*, the other at *Babylon* or *Syracuſe*, mutually agreed ſtrictly to obſerve the Hour and exact Inſtant of the Moon's entering into the Shadow of the Earth, then the Hour of it's greateſt Obſcuration, and finally the Inſtant of it's total Emerſion from the Shadow.

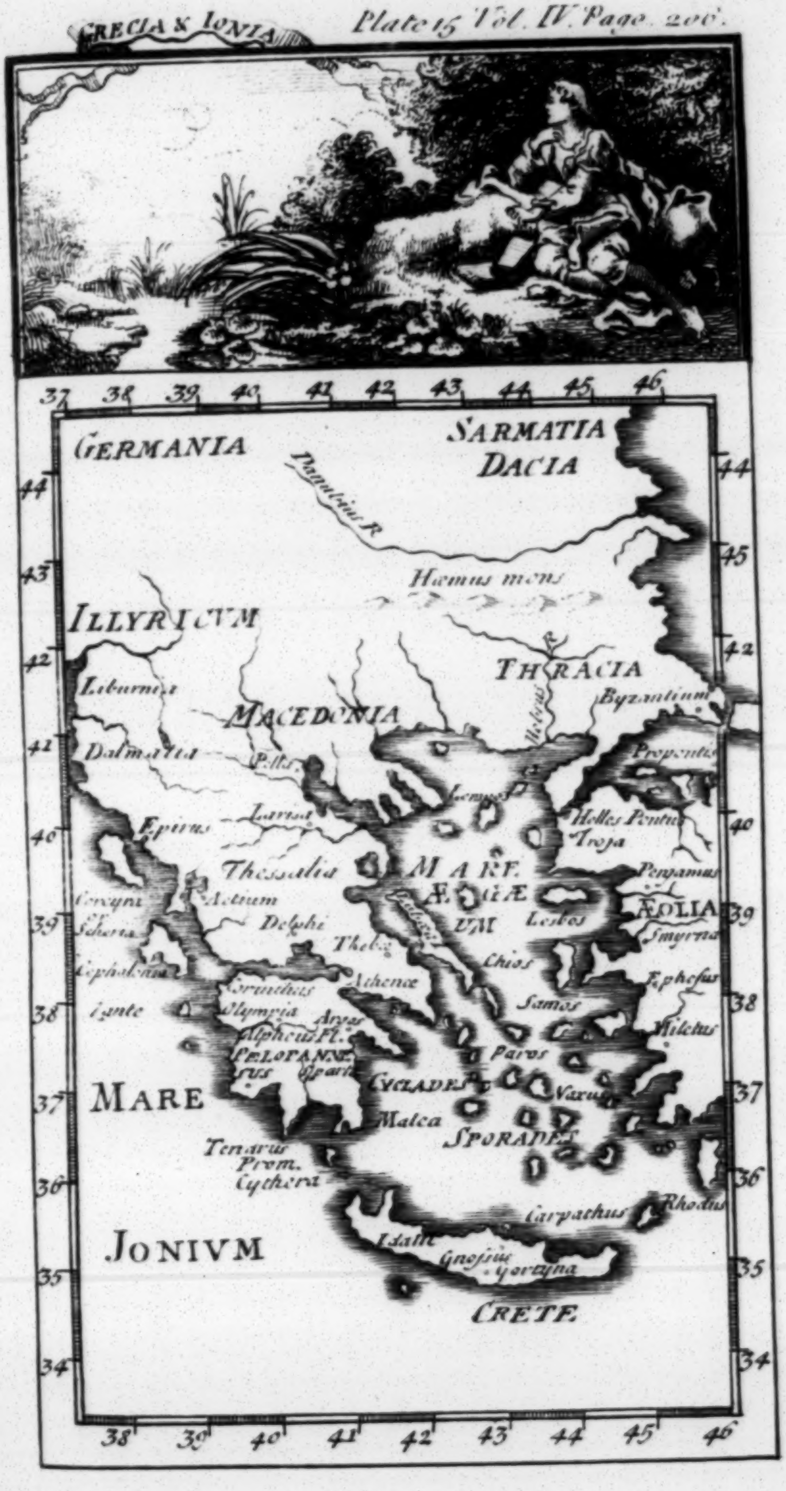
Geographical Meaſures.

As they were ſure, that when the Moon is obſcured with Regard to one Nation, it is ſo with Regard to all the reſt; becauſe it is eclipſed only on account of it's being deprived of the borrowed Light which makes it viſible; they put their Obſervations together, in order to compare the Difference between the Hour reckoned by one of the Obſervers, and that marked out by the other. As it was eaſy for them to know the exact Diſtance that was between two Cities equally diſtant from the Equator, and one of which had the Sun an Hour ſooner than the other, when they ſaw, that there was a Difference of ſo many Hours between the Inſtant of the Eclipſe at *Babylon*, and the Inſtant of the ſame Eclipſe ſeen for Inſtance at *Syracuſe*; they thence concluded, that *Babylon* was by ſo many Hours more to the Eaſt, and conſequently, that there, ſuch was the Diſtance from *Babylon* to *Syracuſe*. It muſt be owned, that the Facility we now have of meaſuring Time in an uniform Manner with our Pendulums, has rendered theſe Obſervations much more exact among us: But the Glory of our Exactneſs and our Progreſs, may be carried back as far as *Thales*. We make uſe of what he has diſcovered; and if we were to determine whether had ſerved us better, he who firſt foretold the Return of Eclipſes, or he who ſubſtituted Pendulums to our Balance-Clocks, it might be Matter of mature Deliberation.

The Roundneſs of the Earth.

Another Advantage that ſprung from the Obſervation of lunar Eclipſes, was the Certainty of the Roundneſs of the Earth, not very well known before that Time. The Eaſtern Nations gave the Earth the Name of *Tebel*, whence came our Word *Table*; becauſe it was indeed an univerſal Prejudice, that the Earth was a flat Surface terminated by an Abyſs of Water. The Poets favoured this Prejudice, by always ſpeaking of the Riſing and Setting of the Stars, as if they came out of the Bottom of the Ocean in the Morning, and went thither again to cool themſelves at Night. A poor Philoſophy truly! a pitiful Jargon! which our Poets are ſtill as fond of, as they are of the Rubbiſh of Paganiſm; as if it were not as meritorious to repreſent Nature in it's Beauty, as to paint imaginary Trifles. The *Ionian* School ſhook off theſe Prejudices;

Plate 15 Vol. IV. Page. 206.



judices: They not only underſtood, that the Moon ſhone with only a borrowed Light, and that it was obſcured only by the exact Interpoſition of the Maſs of the Earth between the Moon and the Sun; but judging beſides of the Figure of the Earth, by that of the terreſtrial Shadow, which gradually was thrown upon the Diſk of the Moon, they could no longer doubt of the Roundneſs of the Earth.

Anaximander and the other Succeſſors of *Thales*, perſevering in this reaſonable and uſeful kind of Study, began to collect the Hiſtories of famous Expeditions, the Accounts of Travellers, and the Memoirs of Pilots, and to compare the whole with their Obſervations. They preſumed to give the Deſcription, Figures, Diſtances, and Relations, of the known Countries. According to ſome of the Learned, the Philoſophers of the *Ionic* Sect collected all theſe particular Branches of Knowledge in one Sphere or Syſtem, and for the firſt Time ſhewed *Greece* a terreſtrial Globe. According to ſome others, they only produced geographical Maps, and local Deſcriptions.

'Tis likely, that this primitive Geography was as yet very imperfect, and that Falſhood did every where disfigure Truth therein: But it was no ſmall Point gained to have begun; and ever ſince that Time, Emulation, the Love of Sciences, Mathematics, Commerce, and Navigation, went on Hand in Hand, and always increaſing among the *Greeks*. They became as famous by their Colonies, as the *Tyrians* were. *Syracuſe* in *Sicily*, *Marſeilles* on the Coaſt of *Gaul*, *Cyrene* in *Africa*, and *Naucrate* in *Egypt*, are not the leaſt of their Eſtabliſhments. They maintained the Liberty of the *Eolians* and *Ionians* their Brethren, who were often troubled in *Aſia* by the Covetouſneſs of the Miniſters of the Kings of *Perſia*. They kept the Sea, in Spite of the numerous Fleets of that formidable Empire: they at laſt deſtroyed it, and were beholden for theſe good Succeſſes to their Education and Knowledge, rather than to their Forces, which were no Way comparable to thoſe of the *Aſiatic* Monarchy.

The Conqueſts of *Alexander*, which changed the whole Face of the Univerſe, gave Sciences quite a new Form. That Prince, as fond of Learning as he was brave, and full of the noble Ideas which his Maſter *Ariſtotle* had inſpired him with, had always about him learned Men, who were appointed to collect for him the Diſtances of Places, the ſeveral Particulars of Natural Hiſtory, and all the Obſervations made by the Nations whoſe Provinces he marched over. And after having ſo often endangered his Life, to free *Greece* from the Yoke and Vexation of the *Perſians*, he expoſed himſelf, barely to make the Diſcovery of ſome new Countries*. He went as far as the *Indian* Ocean, and had like to have been carried away with his whole Army, by the Rapidity of the Tide, with which he was not at all acquainted. His Raſhneſs every where ſucceeded. Aſtronomy, Geography, and Hiſtory, gained very much by it; and though his Empire was divided almoſt as ſoon as it was formed, his Succeſſors, the Poſterity of *Lagus* in *Egypt*, that of *Seleucus* in *Syria*, and the others who divided *Aſia Minor* and *Macedonia*, being originally *Greeks*, the *Greek* Tongue became an univerſal Language, a trading Tongue, which put all the Nations of the three Parts of the ancient World into a mutual Correſpondence. The Weſtern Nations began to know the Riches, the Productions, the Cuſtoms, and the Hiſtory of *Aſia*. 'Tis true, the *Greek* Philoſophers had not taught Men the wholeſome Truths of Religion. But by thus exciting a general Curioſity, and an Eagerneſs for Inſtruction, they inſenſibly prepared all the Nations of the Earth, for the receiving of a Doctrine much fuller of Light, and for ſubmitting to the Goſpel.

Of all the Succeſſors of *Alexander*, none did more Service to Aſtronomy than the *Lagid* Kings. The Wiſhes and Inclinations of great Kings are always efficacious, and they ſoon ſee thoſe Branches of Learning flouriſh which they think fit to reward. The *Ptolemies* judging nothing to be more worthy their Favours than the Works of Aſtronomers, *Alexandria*, their Capital, became the School of that Science. *Conon*, *Ariſtides*, *Timocharis*, and many others, were very eminent that Way, and made Obſervations uſeful to Navigation. *Eratoſthenes*, Keeper of the Library of *Alexandria* in the Reign of *Ptolemy Euergetes*, undertook to calculate the Number of *Stadia*, (or Meaſures of 125 Paces long) that might make up the Circuit of our Globe, and he had the Glory of coming near the Truth. He knew, that at the Summer Solſtice the Sun paſſed through the vertical Point of the City of *Sienna*, being on the Confines of *Egypt* and *Ethiopia*, under the Tropic of *Cancer*. There was at *Sienna*, a Well made on purpoſe for that Obſervation, which about Noon, on the Day of the Solſtice, was wholly enlightened within by the Sun perpendicularly over it *. It was a well known Fact, that at 150 Stadia round about, Styles raiſed perpendicularly on an horizontal Surface, projected no manner of Shadow †. Having ſuppoſed *Alexandria* and *Sienna* to be pretty near under the ſame Meridian, that is, in one and the ſame Line drawn from Pole to Pole, he obſerved in *Alexandria*, on the Day of the Solſtice, the Diſtance of the Sun from the vertical Point, by the Shadow of a Style raiſed perpendicularly on the Bottom of a half concave Sphere, and pointing out by its upper Extremity the Centre of the Sphere, of which it was the Radius. Had that Needle projected no Shadow, it would have been becauſe the Sun was perpendicularly over that Place. He then could judge of the Diſtance of the Sun from the vertical Point, by the Diſtance of the Top of the Shadow from the Foot of the Needle. He found that that Diſtance was the fiftieth Part of the Circumference of an entire Circle; whence he concluded, that as the Sun, at that Time perpendicular over the City of *Sienna*, was diſtant from the vertical Point of *Alexandria*, by the fiftieth Part of the Circumference of the whole Heaven; *Alexandria* was diſtant from *Sienna* by the fiftieth Part of the Circumference of the whole Earth. Now it was an eaſy Matter to know the Diſtance that was between theſe two Cities, and to repeat it fifty Times. Having then calculated that Diſtance to be five thouſand Stadia, he found that the Circumference of the Earth was 250000 Stadia, which being reduced into common Leagues of 24 Stadia each, made 10416 Leagues, and 16 Stadia. This came very near the Computation of the Moderns; according to which, the Circuit of the Earth is judged to be ſomewhat more than 9000 common Leagues.

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* *Quint. Curt.* l. 9. c. 6.

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* *Plin.* 2. c. 63.

† *Umbras nuſquam flectente Syene.* Pharſ. l. 2. v. 587.

Hipparchus, a great Obſerver of the ſame School, diſtinguiſhed 1022 Stars, and gave each of them a particular Name.

While the *Greeks* were making this great Progreſs in the Study of Nature, the *Gauls*, our Fathers, did not neglect it, and their Druids had at leaſt ſome cuſtomary Notions of it, which they communicated *viva voce* and unwritten to their Diſciples, to oblige them to know more certainly the Things which, in Time of Need, they could find no where but in their Memory. But the Inhabitants of *Marſeilles* having been for a long Time Maſters of a very flouriſhing Trade, and being deſirous to extend it in the Ocean, as well as in the *Mediterranean*, they encouraged by Rewards ſuch Aſtronomical Obſervations as might aſſiſt their Navigation, and, by making them a Way to new Countries, afford them new Means of gathering Riches. In the very Time of *Alexander*, *Pytheas* had raiſed a Gnomon in *Marſeilles*, and meaſuring the Length of the Shadow at the Day of the Solſtice, and then comparing it with the Height of the Gnomon, he determined how much the Sun was diſtant from the Zenith of *Marſeilles*, and conſequently how much that City was diſtant from the Tropic and the Æquator. He found, that on the Day of the Solſtice the Length of the Shadow of a Needle is to the Height of the Needle itſelf, what 41 is to 120 A Proportion which Mr. *Gaſſendi* found again to be the ſame at *Marſeilles*, above two thouſand Years after the firſt Obſervation *. *Pytheas*, the better to ſerve his Country, undertook to traverſe the whole *Mediterranean* to the very Bottom of the *Meotide Lake*, where the River *Tanais* diſcharges itſelf. He afterwards ventured to advance through the Ocean to the very Bottom of the North. He obſerved along the Coaſts, (very likely of *Norway*) that towards the Summer-ſolſtice the Sun remained but three Hours under the Horizon, and that as he advanced ſo far as the Iſland *Thule*, which can be no other but *Iceland* or *Lapland*, he ſaw the Sun diſappear for an Inſtant, and immediately after re-aſcend the Horizon. When we treat of the Sphere, you will ſee, that the Sun deſcribing the Line of the Tropic on the Day of the Solſtice, he of Neceſſity muſt be ſeen four and twenty Hours together, or hide himſelf for only an Inſtant behind the Mountains that bound the Horizon, in thoſe Countries where the Tropic is wholly in the viſible Hemiſphere, and grazes along the Horizon with only its inferior Limb. In this, *Pytheas* advanced nothing but what was exactly true. Experience agrees with him; and the Geographers of *Alexandria*, who were ſenſible of the Conformity of this Relation with their Principles, did not fail to make uſe of it, to diſtinguiſh Climates and the Diverſity of the Days from one Climate to another.

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* In the Year 1636.

'Tis true, *Pytheas* had ſtill many Prejudices as to the Structure of the World, which, together with ſome certain Appearances, contributed to deceive him. He was ignorant of the Rotundity of the Earth, and among other falſe Notions which he entertained concerning the Diſpoſition and Situation of the Northern Countries, he thought he ſaw very diſtinctly the Heaven ſupported by the Earth, like an inclined Arch, and forming at it's Extremities a very long Angle, where People were ſtraitly confined, and obliged to ſtoop. *Strabo*, the moſt judicious of the ancient Geographers, was much in the right, when he exploded Accounts like theſe. But he himſelf is much miſtaken, not only when he thinks the Northern Countries uninhabitable, but alſo when he treats as Fables the Obſervation of the Height of the Solſtice at *Marſeilles*, and the Diſcovery of the perpetual Decreaſe of Night, as we advance in the North, at the Approach of the Summer-ſolſtice: Which ſhews, that *Strabo* who was acquainted with the Roundneſs of the Earth, and the Inequality of the Declinations of the Sun, did not himſelf draw proper Conſequences therefrom. The Teſtimony of all Navigators is in Favour of *Pytheas*, and he is the firſt who cauſed Men to uſe the proper Cautions towards regulating the important Navigation of the North, by informing us of the Advantage of going thither in the Spring, and of preventing the Return of the Ice, and of the long Nights, which could never be avoided, ſhould we expoſe ourſelves thereto at the Approach of Autumn.

Phyſics among the *Romans*.

If we paſs on from the Knowledge of the *Gauls* to that of the *Romans*, we ſhall find, that military Diſcipline and Politics were long their only Philoſophy. But when they had once taſted the Arts and Sciences of the *Greeks*, they applied themſelves much leſs to Phyſics and to Experiments, which are always long and toilſome, than to Queſtions of mere Speculation; becauſe theſe exerciſed their Minds without tiring them, and gave them an Opportunity of ſhewing at little Expence, ſome Learning, and a polite Style *. Let us do many of them Juſtice; they often looked in the Improvement of their Reaſon for Means of Employment, and for Comfort in their Troubles: But, generally ſpeaking, their Curioſity was over-powered by Idleneſs. Phyſics and Aſtronomy met with but very few Favourers amongſt them. Neceſſity rather than Inclination, rendered *Scipio*, *Pompey* and *Julius Cæſar*, favourable to thoſe noble Sciences. Theſe great Men, always taken up with Projects, and buſied about Voyages and Conqueſts, were fully ſenſible of the Value of the Knowledge of Times, Places, and Diſtances. *Scipio Africanus* for a long while employed *Polybius*, in running over the Coaſts of the *Mediterranean*, in order to write for him exact Memoirs thereon. *Pompey* kept an Epiſtolary Correſpondence with the Aſtronomer *Poſidonius*, who had more particularly applied himſelf to calculating how many Miles a Degree of the Circuit of the Earth contained, and to the meaſuring of that Circuit by the known Diſtances of ſome ſelect Towns placed under the ſame Meridian, or under a Line drawn from from North to South, in order to judge of the whole by a Part.

Julius Cæſar, who had early applied himſelf to theſe particular Branches of Learning, and knew how to be ſucceſſively a Warrior, an Orator, a Pilot, and a Carpenter, was moreover one of the moſt learned Geographers of his Time. He was become ſo by his perpetual Voyages, by the inſtructive Memoirs he cauſed to be ſent to him from all Parts, and chiefly, by the Care he took to judge of every thing by himſelf, and to keep a faithful Journal thereof. We ſee him paſſing into *Great Britain* with Water-clocks, in order to have an uniform Meaſure, fit to make him know exactly the Difference between the Length of Nights in *Britain*, and of thoſe in *Gaul*. He found the former ſhorter toward the Solſtice; and he may be ſaid to have been a very great Naturaliſt, as he was a great Obſerver.

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* See *Tully*'s Philoſophical Works.

In order to make himſelf a good Geographer, he could not help being an Aſtronomer. On this is grounded the Diſcourſe which *Lucan* cauſes him to addreſs to one of his Prieſts, from whom he hoped to learn the Origin of the overflowing of the *Nile*. “ In the midſt of my military Expeditions, ſaith *Cæſar* to him, I always gave “ a few ſpare Hours to the Obſervation of the Courſe of “ the Stars, to the ſeveral Aſpects of the Heaven, and “ the Knowledge of Celeſtial Things. I even dare hope, “ that *Eudoxus* [a] will not for the future be more famous by the *Ephemerides* he gave to *Greece* at his “ Return from *Egypt*, than I ſhall be by the Order to “ which I have reduced the Courſe and Order of the “ Year [b].”

And indeed, no Body is ignorant of the Care he took, to render the Method of computing the Year more agreeable to the exact Duration of the annual Courſe of the Sun. The Years meaſured according to his Calculation, are for that Reaſon called *Julian* [c]; and in Acknowledgement of this uſeful Reformation, his Name was given one of the Months of the Year. *Auguſtus* [d] obtained the ſame Honour, for having facilitated the Study of the ſeveral Elevations of the Sun, by Means of the Shadow of an Obeliſk 111 Foot high, which he cauſed to be erected in the Field of *Mars*, and for having cauſed the Account of the Lengths of all the Coaſts and Roads of the Empire, drawn up from the Memoirs of his Son-in-law, *Agrippa*, to be regiſtred in a Portico built for that Purpoſe.

But the two moſt learned Men in this kind that ever lived under the *Roman* Emperors, are *Pliny* the Naturaliſt, and *Ptolemy* of *Alexandria*, the one a hundred [e], and the other one hundred and fifty Years [f] after Chriſt; both very great Geographers: The latter however, was a be ter Aſtronomer than a Geographer.

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[a] A Diſciple of *Plato*.

[b] ------*Media inter prælia, ſemper*
Stellarum, cælique plagis, ſuperiſque vacavi,
Nec meus Eudoxi vincetur faſtibus Annus. Pharſal. l. 10.

[c] The Month of *July*.

[d] The Month of *Auguſt*.

[e] Under *Domitian*,

[f] Under *Marcus Aurelius*.

Pliny being weary of the Philoſophy of the School on Account of the Futility of the Matters there treated o and of the Indecorum of the perpetual Diſputes th reigned there, formed the Project of collecting uſef Branches of Learning, fit both to adorn the Mind, an enrich Mankind. He then collected all he could on thoſ Subjects, which naturally ought to buſy Man; ſuch as ar the general Order of the Heaven, the Deſcription of th Earth, or of the known Countries, the Birth and Educatio of Man, the Invention and Progreſs of Arts, the Terreſtrial Animals, the Aquatic, the Amphibious, the Birds, the Inſects, the exotic Trees, the odorous Spices, th Fruit and Foreſt-Trees, the Culture of Plants, the ſevera Kinds of Corn, Huſbandry, the Uſes of Flax, Gardening, Medicinal Plants, Flowers, Botanics, Phyſic, Metals, Metalline and coloured Earths, Stones and Jewels: This is his whole Book. It was hardly poſſible to make a more judicious Choice.

It muſt be owned, that *Pliny* received what was told him with too much Eaſineſs; that he would have ſerved us to better Purpoſe, had he made Criticiſm and Experiments to go Hand in Hand with his Reſearches; that in ſhort the Style of his Work, though full of Sublimity and Fire, every where has a Touch of the Fault which corrupted Eloquence at that Time, and which will always corrupt it in every Age, I mean the Itch of being witty. But that Book, with all its Faults, is nevertheleſs a Treaſure. If Teachers had a Mind to acquaint themſelves with *Pliny*'s Miſtakes, they might, by ſhewing them in Parts to their Diſciples, be as uſeful as if *Pliny* had told the Truth every where; and they might, together with the richeſt Stock of all the Terms of the *Latin* Tongue, convey into the Minds of Youth ſuch Branches of Learning, as are moſt fit to adorn and afford them Employment for the reſt of their Lives.

Claudius Ptolemy, a Diſciple of the School of *Alexandria*, procured himſelf an immortal Reputation, by his excellent Book, intituled, *Of the great Conſtruction of Planets and Stars*; which we alſo call *Almageſte*, after the Tranſlation which the *Arabians* every where ſpread of it in the ninth Century. Having compiled the Opinions of *Ariſtotle*, *Hipparchus*, and *Poſidonius*, on the Oeconomy of the World, adding his peculiar Opinions thereto, he pretended that the Earth was in the Centre of the World; that there were as many concentric Heavens as Planets; that the firſt Heaven which encompaſſed the Earth, was that of the Moon; that the next Heavens were thoſe of *Mercury* and *Venus*, then that of the *Sun*, next to which were thoſe of *Mars*, *Jupiter*, and *Saturn*: That all theſe Heavens were encompaſſed by that of the fixed Stars; that this laſt dragged the whole away every four and twenty Hours, from Eaſt to Weſt; but that while each of theſe Heavens was thus hurried away by the ſtarry Heaven, or by the daily Revolution of a *Primum Mobile* imagined above the ſtarry Heaven, they had each of them in particular a peculiar Motion, by which they made juſt the oppoſite Revolution from Weſt to Eaſt round the Earth, ſome in a few Months, the Sun in a Year, and the others in ſeveral Years. Some other Aſtronomers having obſerved more Motions ſtill, multiplied the Heavens as they pleaſed, to account for theſe Appearances, and thought they had found good Reaſons, to incloſe one within another, even ſeventy Spheres concentric to the Earth.

We muſt own, that this Contrivance of *Ptolemy*, together with all the Additions of After-times, proves abſolutely unwarrantable, and we ſoon ſhall ſee what Experience thought fit to reform therein. However, it is a great Point gained, to have found, as *Ptolemy* did, mathematical Inſtruments of a determined and certain Utility, and to have imagined in the Heaven, an Order, which, falſe as it was, yet in many Reſpects enabled the Obſervers to give a likely Account of the Motions of the Sun and Moon, to foretel Eclipſes, and to improve Geography by certain Rules.

This laſt Uſe is that which *Ptolemy* himſelf made of his Aſtronomy. He made uſe, as much as poſſible, of the known Diſtances of ſome certain Stars, the Elevations of the Pole above the Horizon of ſeveral Places, and the Compariſon of the Diſtances known on the Earth, with a certain Number of Degrees of the celeſtial Sphere, to determine by how much the moſt famous Cities were diſtant from the Equator, which is called their Latitud or by how much one is more to the Eaſt than anothe which is called Longitude; in ſhort, to make Maps in nitely better than thoſe before him. *Hipparchus* h been reformed by *Poſidonius*, who lived a little befo *Chriſt*: *Poſidonius*'s Maps were reformed by *Marin* d *Thyr*, who lived towards the Middle of the firſt Age o the Chriſtian Æra: Thoſe of *Maryn* of *Thyr* were re formed by *Ptolemy*. But if we now find Fault with th Maps of Meſſ. *Jaillit* and *De l' Iſle*, who rectified ſo man Miſtakes in the Maps and Globes compoſed before them we muſt not be ſurprized at the Faults of which *Ptolemy'* Maps are full.

He knew very well how to obſerve, and make uſe o Obſervation: But he could neither be every where, o have every where Correſpondences. As moſt of his Ca culations were grounded on popular Meaſures, commonl taken without Exactneſs or Regard to the Obliquities and Crookedneſs of Ways and Grounds; it is eaſy to gueſs to how many Miſtakes his Calculations are ſubject. In his Time they but little knew the Northern and Southern Regions, which they thought not to be habitable: Which is the Reaſon why the terreſtrial Diſtances that way were called Latitude, whereas they called Longitude the Degrees of Diſtance from the occidental Border of *Africa* towards the Eaſt, becauſe they knew many more Countries that Way than from North to South. His Maps, which were for a long while the only ones uſed by Warriors, Seamen, and Virtuoſoes, have led Readers into numberleſs Miſtakes. *Africa*, for Inſtance, is there continued of one Breadth much beyond the Equinoctial Line for want of Informations on the Contraction of that large *Peninſula* towards the *Cape of good Hope*. Nay, this made ſeveral of the Learned to affirm, that *Africa* formerly was joined to *America*, and that they had been disjoined by an Earthquake. This Pretenſion is overthrown, by what *Herodotus* taught us of the Voyage that was moſt commonly made of old, from the *Red-Sea* to the *Herculean Pillars*.

Ptolemy does likewiſe place the Country of the *Seres* and the other Parts of *Aſia*, at much too great a Diſtance towards the Eaſt; and we ſhall afterwards ſee, that this

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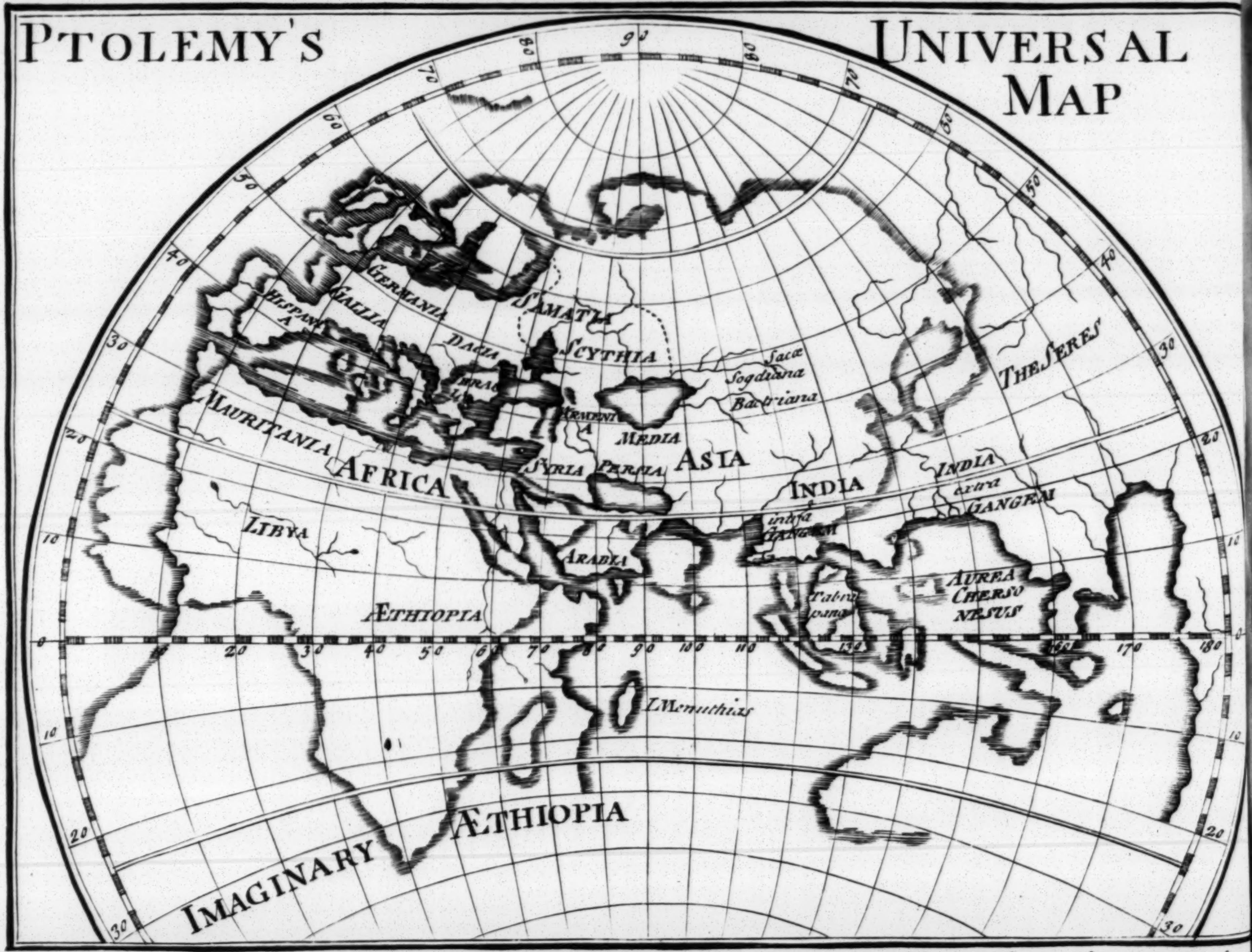

The Coaſts of the Countries as Ptolemy knew & repreſented them, are here expreſsed by Strong Strokes. The ſam Coaſts ſuch as we actually know them, are expreſsed with fainter Strokes. For inſtance, Ceylon, which is the Ancient Taprobana, is much Smaller and is drawn 300. leagues more to the West. The Country of the Seres or China, which ends at the 140.th degree of Longit: is 500 leagues more Eaſtward according to Ptolemy, and even extends it ſelf into th other Hemiſphere.

was the Occaſion of the happy Miſtake of *Chriſtopher Columbus*, who looking for *China* towards the Weſt, on the Teſtimony of *Ptolemy*'s Maps, found *America*, which he had not the leaſt Suſpicion of.

But inſtead of being particular with regard to the Progreſs of Geography, I have contented myſelf, my dear *Chevalier*, here to delineate to you, a little Map of the World, as it was antiently known. I have weakened and left in Uncertainty the Borders of ſuch Countries, as were as yet either unknown or little frequented; and you ſhall ſee there the whole Southern Part of *Africa* ſunk again into its former Darkneſs, by the diſcontinuing of the antient Commerce of *Tarſhiſh*, through the *Red Sea*.

THE INVENTION OF THE GLOBES.

DIALOGUE IV.

THE *Ionian* School, founded by *Thales* at *Miletum*, having had the firſt Ideas of the Rotundity of the Earth, ſeems to have firſt delineated the Repreſentations of it. We know not preciſely, who was the Inventor of the Globes, one of which repreſents the Heaven, and the other the Earth, nor to whom we are indebted for the hollow Sphere made up of Circles, ſo cut as that they may be ſeen through, and fit to expreſs the apparent Motions of the celeſtial Bodies, Theſe Contrivances, very rough and unformed in their Beginning, were improved by degrees. *Hipparchus* and *Archimedes* of *Syracuſe*, about 200 Years before Chriſt, *Poſidonius* ſomewhat more than fifty Years before the ſame Period, and *Ptolemy* about 140 Years after, are the Men, who by the Aſſiſtance of Geometry and Obſervations, contributed moſt to render the Service of Spheres certain and exact, by making them agree with the Aſpects of the Heavens, and the Motions of the Stars. We may ſufficiently inform ourſelves of the Miſtakes of theſe great Men, eſpecially of the laſt, with regard to the Situation and Courſe of the Planets, when we come to the Experiments of later Ages. But their Work having long been the chief Rule of the

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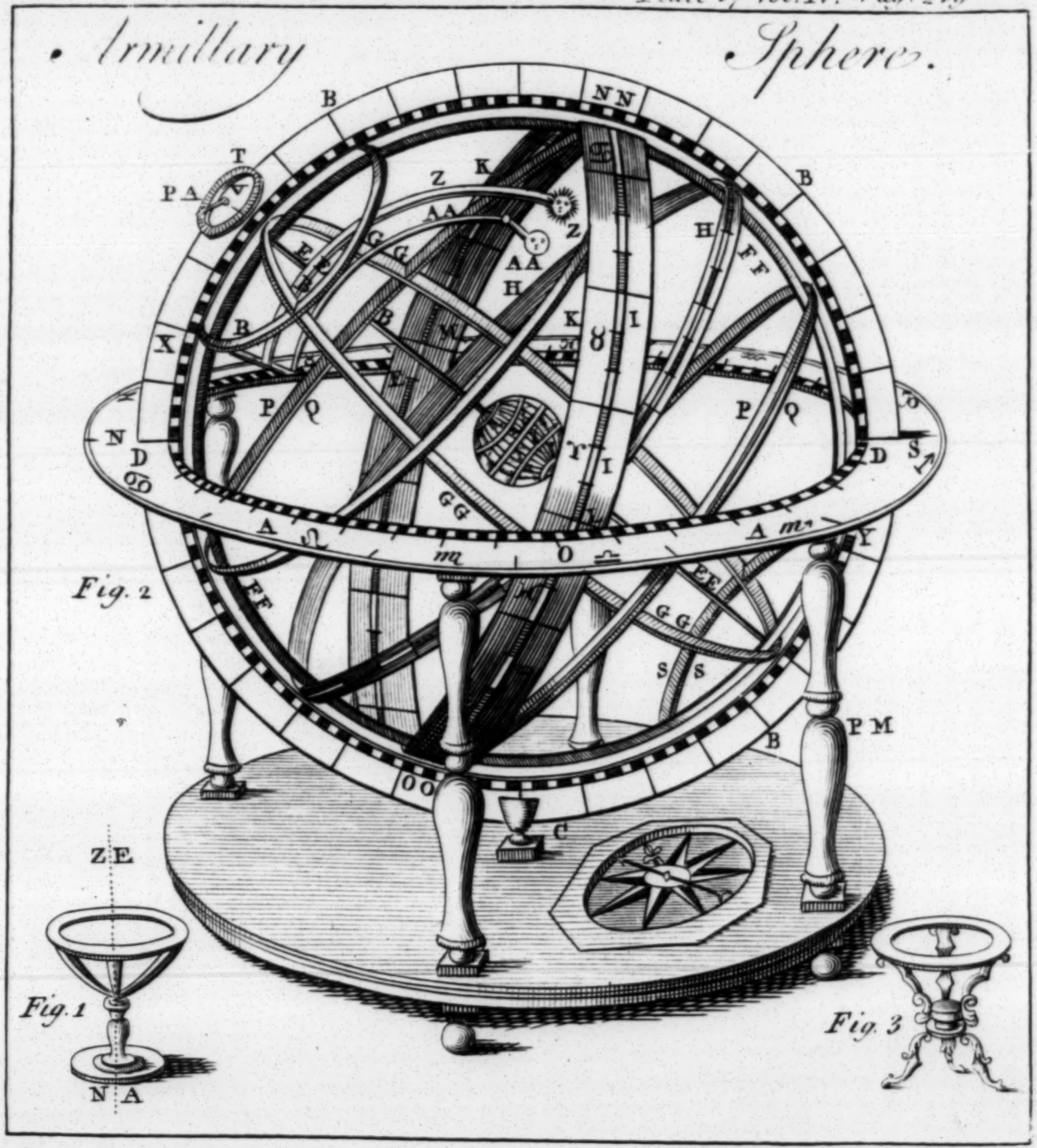

Fig. 1

Fig. 2

Fig. 3

Toms Sc.

Study of the Heaven, and ſtill ſerving in a plain manner to account for the Order of our Days in all Countries, let us be informed of the full Value of what they left us: And we may begin with the Structure aud Uſe of the Armillary Sphere.

The Armillary Sphere.

What they call the Armillary Sphere, is the Collection of ſeveral Circles, ſo diſpoſed among themſelves, as to imitate the ſeveral Lines, that were imagined in the Heaven to repreſent the Path or Paſſage of the Stars, which revolve therein, and the exact Bounds which terminate their Courſes. Whatever we perceive in the Heaven, with regard to us, is ſeen in a concave Sphere. A convex Globe, which is ſeen only without, not being naturally fit to repreſent a Concavity to us, they bethought themſelves of conſtructing a hollow Sphere, in the Inſide of which, all the Points which we are concerned to know might be ſeen, by making it conſiſt of theſe Points only tacked together, and by ſuppreſſing the reſt.

Each Circle, either great or ſmall, is divided into 360 Parts, called Degrees. Each Degree into 60 Seconds; each Second into 60 Thirds; and thus you may proceed with this Subdiviſion, ſo long as you think it fit or poſſible. The Diviſion of the Circle into 360 Degrees, has been preferred to many others, on Account of the Advantage it has, of yielding many Subdiviſions expreſſed by even Numbers, eaſy to be disjoined or collected: 360 may be divided into two Halves, each 180°, or into four Quarters, each 90°. The Quarter may be divided, as Need requires either into three times 30, or into nine times 10, or into ſix times fifteen, or into eighteen times 5. Degrees are marked with (°), Minutes with a little Stroke (′), Seconds with two Strokes (″), Thirds with three (‴), Fourths with (⁗), and ſo on.

The Axis.

The Poles.

The *Axis* of a Circle is a Line which is conceived to paſs through the Centre, and whoſe two Ends, called the *Poles*, are equally diſtant from all the Points that bound the Circle.

The Horizon.

The Horizon which encompaſſes the whole Sphere, is a Circle placed parallel with regard to the Surface of our Abode, on four ſmall Columns *, faſtened on a common Foot, or, better ſtill, on four little Conſoles †, which meet below, to make the whole Machine conveniently revolve on a fixed Foot, by means of an Iron Pin.

The Horizon may much eaſier be ſupported on four Branches, or on two Semicircles of Paſteboard croſſing each other, and faſtened by a ſimple Foot ‡. If we imagine a Line perpendicularly falling on the middle of the Horizon, and having both its Ends equally diſtant from it, it will be the Axis of the Horizon. The two Points which terminate the Axis are called *Zenith* and *Nadir*. The Zenith is above Z E, and the Nadir below N. A.

Z E
N A Fig. 1.

The Meridian, which may be made of Paſteboard, or of Wood, but more uſefully of Braſs, is a large Circle vertically inſerted into the Horizon, into which it enters one Half: It muſt be faſtened there, without being able to deviate either to the Right or Left; but it revolves freely therein downwards from above, and from below upwards, by ſliding in a Groove C, which fixes it upon the Foot, and in two Notches D, made in the Circle of the Horizon.

The Axis of the World E F, is an Iron Rod, which croſſes the ſmall terreſtrial Globe placed in the Middle of the Sphere, and reaches from one Side of the Meridian to the other. The upper End of this Axis is called the Arctic Pole A. P. The under is called the Antarctic or Southern Pole S. P. We muſt not miſtake the Axis of the World, extended from Side to Side of the Meridian, for the Axis of the Meridian itſelf. If we had a Mind to give the Meridian an Axis, by keeping it equally diſtant from all the Extremities of that Circle, the two Ends of it would be in the Horizon, and that Line, together with the Meridian, would cut the Horizon into four Quarters. The two Points through which the Meridian paſſes in the Horizon, are called North and South: North, on the Side towards which the Arctic or Northern Pole N, is inclined: South, on the Side under which the Antarctic or Southern Pole S, is found. The two other Points, at which the imaginary Axis given the Meridian

The Cardinal Points.

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* Fig. 2. † Fig. 3. ‡ Fig. 1.

Meridian cuts the Horizon, are the Eaſt E, and the Weſt W. Theſe four Points are called Cardinal *, becauſe all depends and moves thereupon in the Operations.

They beſides make two other Circles croſs, and revolve on the Axis of the World. Theſe are placed the ſame way as is the Meridian, and are called the two Colures FF, GG; which Name ſignifies *cut* or *mutilated:* And very likely they obtained it on account of the Notches which are made in theſe two Circles, that they may ſupport the others which are to be croſs-wiſe faſtened to them.

The Colures, Fig. 4. κόλουροι, *cæſi.*

The Equator or Equinoctial Circle H, is placed at equal Diſtances from the two Poles of the World, and divides the Globe into two Hemiſpheres, the one called Septentrional or Northern, the other Meridional or Southern.

The Equator.

The Ecliptic I, is a Circle or Line which obliquely cuts the Equator, and which deviates from it twenty-three Degrees and a half on each Side.

The Ecliptic.

This Line is exactly in the Middle of a circular Band, 16 or 18 Degrees broad, and called the Zodiac K. The Zodiac is divided into twelve Portions, every one of which contains 30 Degrees. It encompaſſes the Space of the twelve Celeſtial Signs, under which the Sun is ſucceſſively placed in the courſe of a Year. They made the Band of the Zodiac 16 or 18 Degrees broad, that it might encloſe all the ſpace of the Heaven to which the Moon and Planets deviate from the Ecliptic. The Sun never leaves that Line: The Moon deviates from it to the Diſtance of five Degrees, and ſome Planets ſeven or eight Degrees.

The Zodiac, from Ζώδια, *Animals.* The Celeſtial Signs are almoſt all Names of Animals.

The two Points in which the Ecliptic cuts the Equator, are called Equinoxes, or Equality of the Day and Night, *viz.* the Equinox of the Spring at the firſt Degree of *Aries* L, and the Equinox of Autumn at the firſt Degree of *Libra* M.

The two Equinoctial Points

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* *Cardines,* the Hinges of a Door.

The Points of the Solſtices.

The two Points where the Ecliptic deviates from the Equator, are the Solſtices, or the Bounds of the Courſe of the Sun, *viz.* the Summer-Solſtice at the firſt Degree of *Cancer* N N, and the Winter-Solſtice at the firſt Degree of *Capricorn* O O.

The Tropics.

The two Tropics P Q are Parallel to the Equator, from which all their Points are diſtant 23 Degrees and a half. When theſe Machines are made in large, the true Diſtance is 23 Degrees and 29 Minutes. Nothing is to be overlooked, when the Largeneſs of the Inſtrument admits of that Exactneſs.

That of theſe two Circles which is towards the North, is called the Tropic of *Cancer*, and the other the Tropic of *Capricorn*; of which it touches the firſt Degree.

The Polar Circles.

Let us give the Ecliptic an Axis: This, Axis will deviate from the Poles of the World, or from thoſe of the Equator, which are the ſame, by ſo much as the Ecliptic itſelf deviates from the Equator it croſſes. It recedes 23 Degrees and a half from it: conſequently the Axis of the Ecliptic will deviate 23 Degrees and a half from the two Poles; and if we turn the Sphere about, the Ecliptic will always have its Axis at the Diſtance of 23 Degrees and a half from the two Poles of the World, and there delineate two ſmall Circles, one called the Arctic Polar Circle R, the other the Antarctic Polar Circle S S.

The Horary Circle.

Finally, round the Arctic Pole, and on the Meridian without, the little Circle called the Horary Circle T, divided into 24 equal Parts, is fixed. On the Extremity of the Axis is a Hand V, whoſe End reaches to the Circle; ſo that if you cauſe the Sphere to make a whole Revolution, the Hand which turns together with the Axis, ſhall ſucceſſively paſs over the four and twenty Diviſions of the Horary Circle.

To theſe circular Lines they add two Quadrants, of which it is of Moment well to obſerve the Situation. If you introduce in Imagination an Axis in the Plain, and through the Centre of the Ecliptic, that Plain deviating from the Equator 23 Degrees and a half on each Side, and reſting on the Colure of the Solſtices in N N, and on O O, the Line which you make perpendicularly paſs through that Plain, will reach the oppoſite Sides of the ſame Colure, and exactly at the Diſtance of 23 Degrees and a half from the Pole of the Equator, in X and in Y. Inſtead of an imaginary Hand, or an Index of Metal, which would encumber the Sphere, faſten in the Point X, a piece of Metal, or a Pivot, that may repreſent the Remainder of the whole Axis of the Ecliptic, which had been taken away. Make two Quadrants to revolve on that Point, the one larger, the other ſmaller, with a little Interval between the two, and having both their Extremities under the Circle of the Ecliptic. If you put a little Sun at the End of the large Quadrant Z, and the Figure of the Moon at the Extremity of the ſmaller Quadrant A A; by puſhing with your Finger the two Quadrants, either together, or ſeparately, and contrary Ways, you of Neceſſity muſt ſee the little Figures of the Sun and Moon moving under ſome of the Points of the Ecliptic; ſince theſe Quadrants, which are both of 90 Degrees, revolve round the Axis X, diſtant 90 Degrees on every Side, with regard to the Ecliptic I. For this Reaſon, they make up the Quadrant of the Moon of two broken Pieces, to make the Moon decline *ad libitum*, and expreſs pretty nearly its Deviations from the Ecliptic. I forgot to tell you, that in order to ſet theſe two Quadrants freely in Motion, the Axis of the World E E, muſt be cut in B B, to leave them a Paſſage. The reſt of the Axis E being Iron, will always preſerve its Place without any Diſorder.

They then reckon in the Sphere ſix great Circles, five little ones, two Quadrants, and twelve principal Points. The ſix great Circles, whoſe Plains paſs through the Centre of the terreſtrial Globe placed in the Middle of the whole Machine, and which cut the Earth into two equal Parts, are the Horizon A, the Meridian B, the two Colures F F, G G, the Equator H, and the Ecliptic I. The five little Circles which cut the Sphere into unequal Portions, are the two Tropics P Q, with the Polar Circles R B, S S, and the Horary Circle T, which is not ſo much in, as annexed to the Sphere. The Points of more important Uſe are the Zenith Z E, and the Nadir N A, the Arctic Pole A P, and the Antarctic S P, the North N, and the South S; in the Interſections of the Meridian with the Horizon, the Eaſt E, and the Weſt W, in the ſame Circle; the Equinoctial Points L, M, and the Points of the Solſtices N N, O O. Then let us join to the Axis E E, which ſupports the whole, the End of the Axis of the Ecliptic, with the two Quadrants, the one for the Sun Z, the other for the Moon A A, and we ſhall have all the Pieces together. Let us now come to the principal Uſes made of them: In the mean time you will learn the Reaſons of the Names given them.

Firſt let us obſerve what moſt concerns us in Nature: The Sun which lights us, ſeems every Day to advance from Eaſt to Weſt. Beſides, we ſee it daily changing in a regular Manner, the Points of its Riſing and Setting, and yearly paſſing through the ſame Points again. It then has two Motions, the one called diurnal, the other called annual. The Quadrant Y Z will now illuſtrate both theſe Motions, and though they be contrary to each other, nothing is more eaſy to be conceived, than the meeting of both in one and the ſame Star. Bring the Sun Z to the Equinox of the Spring L, and cauſe the Sphere to make an entire Revolution from Eaſt to Weſt: The Sun placed in the Heavens will be carried away with the Sphere. It will aſcend and deſcend: You will ſee it move from Eaſt to Weſt, and ready to begin the ſame Revolution again. He never leaves the Point of the Ecliptic where he is, and yet you ſee it deſcribe in Space, a Line perfectly like the Equator; ſo long as the Revolution of the Sphere continues, you ſee it juſt under the Equator. If after this Revolution you give the little Sun a gentle Thruſt, and cauſe it to advance towards the Eaſt, you may then bring it under the Meridian, and ſee by how much it will be diſtant from the Equator, of two, or twelve, or twenty-three Degrees, as you pleaſe. If the little Sun is two Degrees diſtant from the Equator, and you cauſe the Sphere to revolve from Eaſt to Weſt, it will paſs through all the Points of Space which are two Degrees diſtant from the Equator. If it happens to be 23 Degrees diſtant from it, it will paſs through all the Points of Space 23 Degrees diſtant from the Equator. If you join all theſe Points in Imagination, you will make of them a diurnal Circle parallel to the Equator, and which will expreſs the Revolution of the true Sun placed at two, or ten, or twelve, or twenty-three Degrees from the Celeſtial Equator. Your repreſenting Sun has two Motions, the one, by which you make it go from one Degree to another, and from Weſt to Eaſt under the Ecliptic, whence it never deviates; the other, by which the whole Sphere, whereof it is a Part, carries it away in a quite contrary manner from Eaſt to Weſt. We may conceive, that it is the ſame with regard to the true Sun. Let us ſuppoſe the Heavens to revolve from Eaſt to Weſt; the Sun, which makes a Part of them, is carried away from Eaſt to Weſt with the whole Maſs of the Heavens: And this is the daily Motion. Let us likewiſe ſuppoſe, that the Sun has a peculiar Motion, by which it advances by very ſlow Steps in the Ecliptic, going from Weſt to Eaſt: This ſhall be the annual Motion. We then ſhall ſee it appear ſometimes under the Equator, ſometimes it ſhall reach the Tropic; then be found between the two: After that it ſhall repaſs the Equator, and by continuing its proper Motion under the Ecliptic, by little and little reach the oppoſite Tropic, without ever advancing farther, becauſe it never leaves the Ecliptic.

The Combination of theſe two oppoſite Motions may, as we already remarked on account of the Moon, be expreſſed by what happens to a Fly placed on the Edge of the broad Wheel of a Crane wrought by Hands. While the Wheel deſcends, the Fly may crawl upwards: The Wheel has one Motion, the Fly has another: But that of the Moon is not preſently perceived. On the contrary, it appears to be carried away as well as the Wheel. However, if the Fly, always aſcending in a contrary Direction to that of the Wheel, obliquely paſſes from one Edge to the other, though we ſee it conſtantly in the Air deſcribing Lines parallel to either Edge; we alſo ſhall ſee it arrive, ſometimes at the middle of the large Wheel (and this repreſents the Sun in the Equator): It ſhall afterwards arrive at one Edge or the other (and this repreſents the Sun in the Tropic). Therefore the daily Motion of the Sun from Eaſt to Weſt, does not properly belong to the Sun: It is rather the Motion of the Heaven, to which it is fixed. But the paſſing of the Sun over all the Degrees of the Ecliptic, going from Weſt to Eaſt, according to the Ancients, is the true Motion of that Star.

The Sun being by this his peculiar Motion got to the Point of the Ecliptic, which is the moſt diſtant from the Equator, as N N or O O, if that Point be carried away with the Heaven, it can be only on a Path every where diſtant twenty-three Degrees and a half from the Equator; and this was repreſented by the Circle of the Tropic, which the Sun ſhall ſeem to deſcribe when arrived at that Point. They give that Circle the name of Tropic and Solſtice, the latter *, becauſe it is the Bound of its Courſe, or of its Remoteneſs, with regard to the Equator. The Name *Tropic*, that is, Reverſion; becauſe the Sun, as it purſues its Courſe through the Ecliptic, leaves that parallel Circle, to draw near the Equator again.

You may give the Moon A A the ſame Motions you cauſed the Sun to make. If you bring the Moon between the Sun and the Earth, you will have an Eclipſe of the Sun: If you put the Earth in the Middle, it is an Eclipſe † of the Moon.

As we ſtudy the Heaven only to know the Relations it has to the Earth, let us now transfer all the Circles juſt mentioned, to a terreſtrial Globe of a reaſonable Size, and where every thing may be better perceived than on the little Globe found in the Centre of common Spheres, and that generally pretty much unformed. You ſee, Sir, that the Poles of that Globe will correſpond with the celeſtial Poles, and make a Part of the Axis of the World: That by delineating on that Globe a Line equally diſtant from both Poles, you will have an Equator in all Points correſponding to thoſe of the celeſtial Equator; that by delineating on it the other Lines with the ſame Proportions, and in the ſame Degrees, you will have a terreſtrial Ecliptic, two Tropics, two Polar Circles, and, in ſhort, all the Points which muſt thereon correſpond with thoſe of the Heaven. All theſe Lines transferred from the celeſtial Sphere on a Globe, divide it into as many Bands or

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* *Solis Statio*, the Bound of the Sun. Τροπαὶ ἠελίοιο, the Return of the Sun. *Hom. Odyſſ.*

† From ἔκλειψις, *deliquium*, Deficiency, comes the Word *Eclipſe*.

The Zones.

broad circular Portions, which are called Zones. The Space round the Globe contained between the Tropics, is called the torrid or burning Zone; becauſe the Sun never leaves it. The two Spaces between the Tropics and the two Polar Circles, are the temperate Zones, one Northern, the other Southern. The Spaces incloſed within the Polar Circles, are the frigid Zones.

Now place your Globe within a Meridian that ſupports its Axis, and put the whole in an unmovable Horizon, wherein the Meridian may ſlide, and the Globe freely revolve. You may then at your Choice, and as need requires, operate either upon the Sphere or on the terreſtrial Globe. What we ſhall ſay of theſe Lines, and of the Uſes made of them, is equally to be underſtood of either of the Inſtruments, which we ſhall alternately handle.

The Origin of the Horizon.

Of all the Circles the Horizon alone ſenſibly exiſts in Nature. The others are almoſt made up of a Train of Points, through which the Sun, or ſome other Star, ſhall have paſſed. Theſe Points may be a real Paſſage: But they are not ſeen, and can only be conceived; whereas the Horizon is compoſed of all the Points that bound our Sight *, or which determine the half of the Heaven, or the upper Hemiſphere which we ſee, and mark out the Separation of it from the inferior Hemiſphere which we do not ſee. Theſe two halves of the Heaven are equal or nearly ſo: For the Earth being as a ſingle Point, in compariſon of the ſtarry Heaven, the Obliquities, and even the whole Body of the Earth, are here of no ſort of Conſideration. They hinder not the Earth from being but a ſingle Point, in the Line or in the Planet that divides the Heaven into two Parts. They hinder not the Eye placed on that Point, from ſeeing the upper half as large, or almoſt as large, as the inferior: And in reality we ſee the Stars diametrically oppoſite, as the *Hyades*, which are in the Forehead of *Taurus* on one Side, and thoſe of the *Scorpion* on the other, appear on the two oppoſite Borders of the Horizon at the ſame Time.

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* From ὄρεα, Mountains that bound our Sight, comes ὁρίζειν, *to bound, to determine.*

The Immobility of the Horizon in Spheres.

The Horizon of every Place being determined by two vertical Points, the one ſuperior, called Zenith Z E, the other inferior, called Nadir N A, both diſtant 90 Degrees from the Borders of that Horizon; if you leave that Place, you change your vertical Points; you of courſe change alſo your Horizon; and if you advance under a new Zenith, five, ten, or twenty Degrees diſtant from the firſt, the new Horizon likewiſe will diſcover five, ten, or twenty new Degrees of the Heaven before, and hide as many behind us, becauſe the Horizon is always, and on all Parts, 90 Degrees diſtant from the Zenith. We therefore ought to have a movable Horizon, that might be turned *ad libitum*, in order to repreſent the Horizon of every Point of the Earth: But it is one and the ſame thing, to place the Horizon at 90 Degrees diſtance from whatever Point you may be pleaſed to chuſe in the Globe, or to turn the Globe itſelf, and bring the propoſed Point to 90 Degrees from the Horizon. For this Reaſon they have made the Horizon firm and unmoveable in Spheres; becauſe it, as it were, multiplies itſelf, and by the Mobility of the Globe becomes the Horizon of all the Points of the ſame. But we cannot find the Horizon of any Place propoſed, without knowing the Uſe of the Meridian.

The Appointment and Uſe of the Meridian.

The Meridian is a great Circle that paſſes through the Poles of the Sphere, through the vertical Points of a propoſed Place, and through ſome Point of the Equator. If we go from North to South on one and the ſame Line, conceived and delineated after this Manner, we change not our Meridian: But if we go from Eaſt to Weſt, we inceſſantly change our Meridian, and we may reckon as many Meridians as there are Points in the Equator. However, as a ſingle Horizon is ſufficient in the Sphere for all the Points in the World, a ſingle Meridian likewiſe may become the Meridian of any Place; ſince by turning the Globe you may bring what Place you pleaſe under the common Meridian, which will ſupply the Place of all others.

As the Horizon cuts the World into two Hemiſpheres, ſo the Meridian cuts the Horizon into two equal Parts, the one Eaſtern, where we ſee the Stars aſcend, the other Weſtern, where we ſee them go down. The Duration of the Day, is that Time in which the Sun appears in our Hemiſphere. The Meridian which divides that Hemiſphere into two equal Parts, does of courſe alſo cut the Duration of the Day into two equal Portions: It is Midday when the Sun touches that Circle; and for this Reaſon it is called Meridian, or the Divider of the Day.

The ſeveral Uſes of the Globe.

The chief Uſes to which the Sphere and Globe are applied, depend on the Knowledge of the Points marked on the Meridian and the Horizon.

The Points marked on the Meridian are, Firſt, The 360 Degrees of the Circle, diſpoſed in four Nineties, which are reckoned from the Equator to the Poles: Secondly, The Climates or ſucceſſive Increaſings of the Days from the Equator to the Poles.

The Points marked on the Horizon are of three Kinds: Firſt, on the inner Border of the Horizon were brought down the 360 Degrees of the Ecliptic, together with the twelve Celeſtial Signs, which were placed by thirties, placing the firſt Degree of *Aries*, and the firſt of *Libra*, in the two Points where the Axis of the Meridian, if it had one, would certainly have been. Secondly, The next Circle in the Horizon contains the twelve Months and the 365 Days of the Year, over-againſt thoſe Degrees of the Ecliptic under which the Sun is in every one of theſe Days. Thirdly, The laſt Round of the Horizon contains the Name of the Winds, according to their ſeveral Quarters.

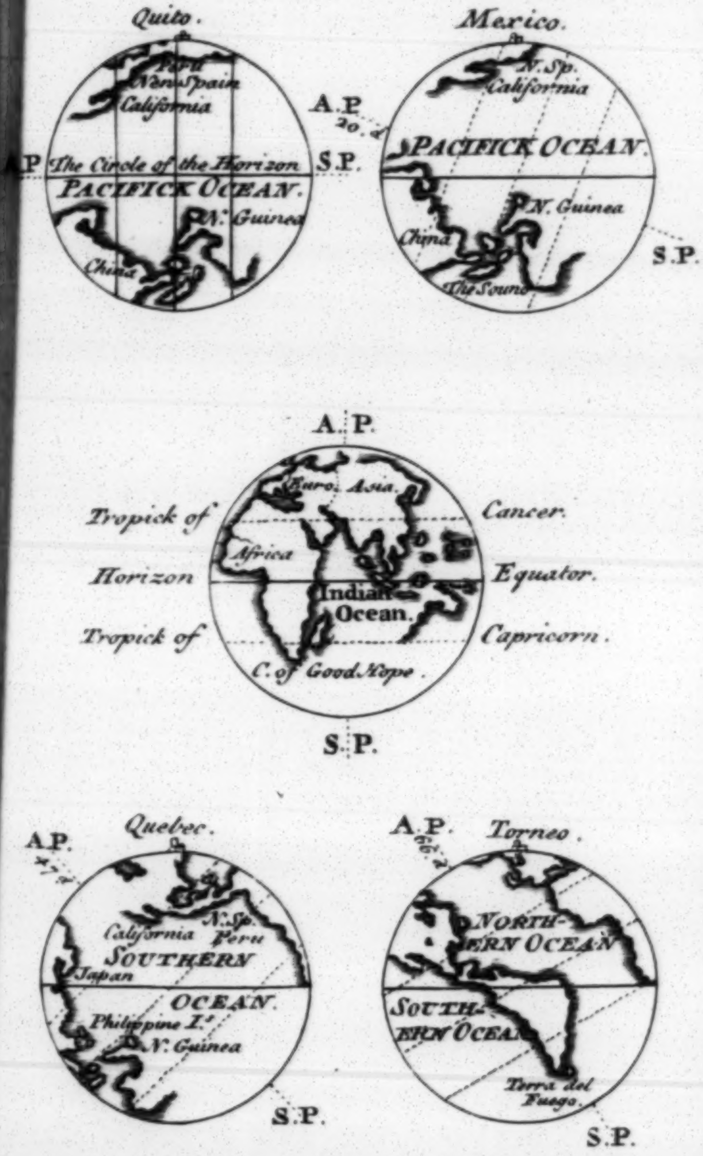
The Preceſſion of the Equinoxes.

This Order of the Horizon is the ſame in the Armillary Sphere, in the terreſtrial Globe, and that which repreſents the Heaven at large, with the Animals which the Stars are named after. But making uſe of a Celeſtial Globe, you, perhaps, will be ſurprized not to find the Kalendar of the Horizon agreeing with the Marks or Figures of the Animals which are delineated in the Ecliptic on the Globe itſelf. In the Horizon, the 10th of *March* correſponds with the firſt Degree of *Aries*, and that firſt Degree touches the Equinox of the Spring, or the Interſection of the Ecliptic on the firſt degree of the Equator on the Eaſt ſide. You likewiſe will find there, the 11th of *June* marked over-againſt the firſt degree of *Cancer*, where is the Point of the Ecliptic the moſt deviating from the Equator; and that is the Summer-Solſtice. You then will ſee there, the 12th of *September* placed over-againſt the firſt Degree of *Libra*, and at the other Interſection of the Ecliptic, on the 180th degree of the Equator, which is the autumnal Equinox. Laſtly, You ſee thereon the 11th of *December* placed over-againſt the firſt Degree of *Capricorn*, where the Ecliptic declines moſt from the Equator toward the South Pole: And that is the Winter-Solſtice. If from the Edge of this Horizon you carry your Eye to the terreſtrial Globe, you will there indeed find the compendious Mark or Character of *Aries*, near the Interſection of the firſt Degree of the Equator; but the Stars themſelves of *Aries*, and the Figure of the Animal which comprehends them within its Extent, are thirty Degrees farther towards the Eaſt. All the compendious Marks of the other Signs are placed on the reſt of the Ecliptic as they are marked on the Horizon. But the Signs themſelves, or the Animals with their Stars, begin 30 Degrees farther towards the Eaſt. Whence can this enormous Difference between the Kalendar of the Horizon, and the Order marked on the Globe proceed?

This Difference is what they call the Preceſſion of the Equinoxes. The firſt Aſtronomers who conſtructed the Sphere, took care to place the firſt Degrees of the Signs juſt named, at the Points of the Equinoxes and Solſtices. They had reckoned thus of a long Time, and they were perſuaded, that the Stars ſeen in thoſe Points never left them. However, they obſerved by degrees, that the firſt Star of *Aries* deviated by the Space of a Degree from the Point of the Equinox towards the Eaſt, and that within the ſpace of ſeventy Years; and now all the Signs are at laſt advanced 30 Degrees towards the Eaſt, and diſtant from thoſe Points to which they gave their Names. But theſe Points ſtill keep the Names of the Signs, which are no longer there: Though the Sun, on the 10th of *March*, be under the firſt Degree of *Piſces*, they ſtill ſay as formerly, that it enters *Aries* on that Day. It is the ſame with the reſt reſpectively: Which, by the by, is a new Matter of Shame and Confuſion to Aſtrologers. They

give

The aspects of the Heaven.



Ja. Mynde Sculp.

give to *Libra* benign and favourable Influences, to the *Scorpion* Malignity, and the other Signs Effects agreeable to the Nature of the Animals or Objects of which theſe Signs bear the Names. More eſpecially they pretend, that the whole Activity of the Influence appears, the Moment when ſuch or ſuch a Sign begins to aſcend the Horizon: But their Pretences are moſt frivolous; ſince when they ſay, a Man is born under the dangerous Aſpect of *Scorpio*, it was really the Sign *Libra* which came above the Horizon, the Moment of that Man's Birth, and it is the Sign *Gemini* which aſcends, when they talk of *Cancer*, and ſo of the reſt.

As the whole Sphere, or the Globe, may ſucceſſively have all their Points brought under the Meridian, and the Meridian may lower or heighten the Axis of the World, by ſliding within the Notches of the Horizon; it is an eaſy Matter for us to determine the Aſpects of the Heaven, with regard to all the People of the Earth; to meaſure the Diſtances of Places, to know the Duration of Days and Nights for ſuch or ſuch Places, the Moment of the riſing and ſetting of the Sun, the Hour of its being in ſuch or ſuch Place, when it is Mid-day in another; in ſhort, to anſwer, by the Help of a Sphere or Globe, all the Queſtions relating to the Situation of Places, either with regard to each other, or with regard to the Sun and the whole Heaven.

The ſeveral Aſpects of the Heaven.

If we have a mind to know the ſeveral Horizons of Nations, and the Manner in which they ſee the Sun, we muſt begin by looking into the Aſpect of the Heaven, with regard to thoſe People who are under the Equator. And that we may judge of all by a ſingle one, let us, for Inſtance, take the City of *Quito*, ſituated on the Northern Limits of *Peru*, at a Diſtance pretty nearly equal from both Poles of the Earth.

* Bring *Quito* under the Meridian: The Degree of the Meridian which ſhall correſpond to it, will be the Zenith of *Quito*. Raiſe that Zenith above the Horizon, till you

may reckon 90 Degrees from that Point of the Horizon; Then you will perceive the two Poles of the World brought into the Horizon. *Quito* has then it's Zenith in a Point of the Celeſtial Equator, and at 90 Degrees diſtance from each Pole of the World. In this Situation, the Equator, and all the Circles parallel thereto, muſt needs cut the Horizon directly, and without inclining on one Side more than on another. The Horizon reciprocally cuts the Equator, and all the Circles parallel thereto, into two equal Parts. This is what they call the Rectangular Horizon, or a right Sphere. The Reſults of this Situation are theſe:

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* You may, in order to make the Meridian move without any Hindrance, take off the two Screws that fix the Horary Circle on the Meridian.

The Rectangular Horizon.

We have Day, ſo long as the Sun remains above the Horizon: Now all the Circles which the Sun deſcribes from one Tropic to the other on the Horizon of *Quito*, are cut into two equal Portions by that Horizon, ſince they fall thereon directly. Days are then equal there to the Nights all the Year round, that is, the Day is twelve Hours, and the Nights as much.

As the Sun there deſcends directly under the Horizon, it goes much quicker from it, than if it ſunk obliquely under it. Therefore the Twilight muſt be ſhorter at *Quito*, than in thoſe Places where the Sun croſſes the Horizon obliquely.

The Sun is three Months in its paſſing through the Ecliptic, from the firſt Degree of the Equator to the Tropic of *Cancer*, and three Months more in its Return to the Equator, or the firſt Degree of *Libra*. When it is come to the Point of the Ecliptic which cuts the Equator, it is carried by the Motion of the Heavens, on a Circle which repreſents the celeſtial Equator, and which paſſes vertically over all the Points of the terreſtrial Equator. He then at that Day paſſes through the Zenith of *Quito*, and will again paſs over it ſix Months after. The Inhabitants of *Quito*, and all ſuch as live under the Equinoctial Line, ſhall then twice in a Year ſee the Sun perpendicularly paſſing over their Heads.

The oblique Horizon, or the oblique Sphere.

Let us now leave the Equinoctial Line, and make choice of ſome other well known Place in the torrid Zone: For Inſtance, *Mexico*, the capital of *New Spain*. I bring this under the Meridian, and find, that it correſponds to the 20th Degree marked on that Circle. It has then a Zenith 20 Degrees diſtant from the foregoing, and from the Celeſtial Equator in which the Zenith of *Quito* is. When we were at *Quito*, our Horizon touched both Poles. All the Stars revolving round the Poles with the Heaven, roſe and ſet in that Horizon. The Horizon of *Quito* cut in half all the Circles deſcribed by each individual Star. The only Points of the Poles remained invariable, and in the Horizon. But now that we are brought to *Mexico*, it is no longer thus. We have removed twenty Degrees from the Equator towards the Arctic Pole. Our Horizon muſt no longer terminate in the Arctic Pole, but be twenty Degrees lower down, and riſe behind us twenty Degrees above the Antarctic Pole, which will then be hidden. We therefore determine the Horizon of *Mexico*, and of any other Place, by elevating the Pole above the Horizon, as many Degrees as the Place intended is diſtant from the Equator. For bringing the Horizon under the Pole, or elevating the Pole above the Horizon, is one and the ſame Thing; and we only elevate the Pole, becauſe the Horizon is fixed both in Globes and Spheres.

In this new Diſpoſition of the Sphere, which is called Oblique, I find every thing different. The Equator alone is cut into two equal Parts by the Horizon. The Tropic of *Cancer*, which is nearer the elevated Pole, is more above than it is under the Horizon; and the Tropic of *Capricorn* on the contrary, which is nearer the depreſſed Pole, is now cut by the Horizon into two inequal Parts, the ſmaller of which is in the viſible Hemiſphere, and the larger in the inferior. All the Circles parallel to the Equator, which the Sun deſcribes from Day to Day, by the Motion of the Heaven that carries it with itſelf, will be proportionably cut with the ſame Inequality. The Inequality will be leſs, in Proportion as the diurnal Parallels ſhall be leſs remote from the Equator. The Portion of the Circle the Sun ſhall deſcribe above the Horizon of *Mexico*, will always be ſmaller and ſmaller, as it draws towards the Tropic of *Capricorn*. This diurnal Arch will conſtantly increaſe, in its Progreſs towards the Tropic of *Cancer*. Hence the Increaſe of the Length of the Days, and the Diminution of the Nights, towards the

Summer-ſolſtice: Hence the decreaſe of Days and the length of Nights, as the Sun approaches to the Winter-ſolſtice: Hence in ſhort, the Equality of the Day and the Night, when the Sun deſcribes the Arch of the Equator; ſince the Horizon of *Mexico*, cutting that Circle into two equal Parts, renders the diurnal Arch equal to that which the Sun runs through in the lower Hemiſphere.

Next to this I remark, that the Sun being come in the Ecliptic to 20 Degrees of declination from the Equator, that Day deſcribes, by the Motion of the Heavens, a Circle parallel to the Equator, and paſſing through all the Points which are twenty Degrees diſtant from the Equator. It will then paſs through the Zenith of *Mexico*. Continuing its Progreſs in the Ecliptic, it will decline from *Mexico* only three Degrees and a half towards the North, before it arrives at the Solſtice; ſince the moſt declining Point of the Ecliptic is but 23 Degrees and a half diſtant from the Equator. Continuing its Courſe in the Ecliptic, it will neceſſarily repaſs the Declination of 22°, then gradually will proceed to that of 21, and at laſt, that of 20 Degrees. It will therefore on that Day deſcribe anew, a Parallel, which will paſs again through the Zenith of *Mexico*. It will then, twice in a Year at Noon, paſs directly over the Heads of the People of *Mexico*; and ſo generally over that of all the Inhabitants of the torrid Zone. For, if I bring, for Inſtance, the Town of *La Plata* * on the Horizon, and the Mines of *Potoſi*, which are on the Borders of *Peru* in *South-America*, nearly equally diſtant from the Equator, by raiſing the antarctic Pole 18 or 20 Degrees above the Horizon, I ſhall find the very ſame Effect, and with a Diſpoſition entirely alike. Only the Days which were the ſhorteſt at *Mexico*, ſhall be the longeſt at *La Plata*, which lies on the other Side of the Equator.

Let us now return to *Mexico*, and look what are the Days of the Year when the Sun is to paſs through the Zenith of that or any City. The Operation for one will ſerve as a Rule for all the reſt: We need only ſee, what are the Points of the Ecliptic which paſs under the twentieth Degree of the Meridian, where I am inform'd that the Zenith of *Mexico* is. By turning round the Globe, I ſee two Points of the Ecliptic paſſing under the twentieth Degree of the Meridian. Firſt, I ſee the 26th Degree of *Taurus*, and continuing the Revolution, the third Degree of *Leo* paſſing under it. I look out in the Horizon, to know what Days of the Year correſpond with both theſe Points. I find that the 18th of *May* anſwers to the 26th Degree of *Taurus*, and the 26th of *July* to the third Degree of *Leo*. I then thereby know, that the Sun paſſes perpendicularly over *Mexico* on the 18th of *May*, and the 26th of *July*; and as it recedes but very little from the Zenith of *Mexico*, before it comes to the Solſtice, which declines but three Degrees and a half from it Northward; the Sun, for three Months together, paſſes at Noon almoſt directly over that City, and the Heads of all the People near the Tropics. The Summer ought conſequently to be much more inſufferable there, than in the middle of the torrid Zone, and under the Equinoctial Line, from which the Sun deviates much faſter. But we have already obſerved * from the agreeing Accounts of Travellers, that by a ſpecial Providence of the Creator, the *Eteſian* Winds bring towards the Tropics, when the Sun draws near them, ſuch a vaſt Quantity of Fogs and Rains, that the Summer, which ought to roaſt them, in reality becomes their Winter, or the coldeſt Seaſon they have.

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* *La Plata*, in *Spaniſh*, *the Silver*. The Silver Cito, thus called on account of the Mines of that Metal in it's Neighbourhood. They abandoned them, to give their whole Care to the Silver Mines of *Potoſi*, eighteen Leagues from *La Plata*.

As the Pole is twenty Degrees above the Horizon of *Mexico*, the Stars, which are leſs than twenty Degrees off, will never ſet with regard to that City; ſince the Circles they deſcribe, never fall under the Horizon, and are never interſected by it. Therefore the *Urſa minor* will be ſeen every Night at *Mexico*. But the *Urſa major*, which is a great deal more than 20 Degrees diſtant from the Pole, ſhall riſe and ſet there. Whereas it is always ſeen in our Climate, becauſe as we are 49 Degrees diſtant from the Equator here at *Paris*, our Pole is ſo much elevated. Now the Limits of the Circle which the ſeven Stars of the Chariot or *Charles's-Wain* deſcribe round the Pole, recede only forty Degrees from the Pole: They then do not go down under the Horizon: Nor do they ſet with regard to us.

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* Volume III.

Let us now bring under the Meridian, ſome Country that ſtands in the Middle of the temperate Zone, as *Hungary*, *Auſtria*, *France*, *Acadia*, or the *French* Colony, which now inhabits both Sides of the River *St. Lawrence*. We, for Inſtance, ſhall find *Quebec*, which is the capital Town of *New France*, 47 Degrees diſtant from the Equator. The Pole elevated 47 Degrees above the Horizon, ſhall give us the Aſpect of the Heaven, anſwerable to the Situation of the capital Town of *Canada*. In this Situation we ſhall ſee one half of the Equator above, and one half under the Horizon; but at the ſame Time all the diurnal Parallels cut with a greater Inequality than at the Horizon of *Mexico* they were. The Tropic of *Cancer*, which riſes above the Horizon, together with the Pole adjacent, has almoſt a two-third Part elevated above the Horizon. The Day muſt then, in the Time of the Solſtice, be there almoſt two Thirds of four and twenty Hours long. On the contrary, the Horizon cuts the Line of the Tropic of *Capricorn* in ſuch a Manner there, that it has almoſt a two-third Part ſunk under the lower Hemiſphere. Days muſt then be there, but eight Hours, or ſomewhat more, towards the twenty-ſecond of *December*. We ſoon ſhall ſee, how the little Horary Circle, with its moving Hand, ſhews us the Duration of Days on every Horizon, without Trouble or Calculation.

Let us make our laſt Station within the Space which extends from the Equator to the Pole, and let us ſtop at *Torneo*, a large Town which we find at the Bottom of the Gulph of *Bothnia*, terminating the *Baltick-Sea*, at the Entrance of *Lapland*, and almoſt under the arctic polar Circle. *Torneo*, when brought under the Meridian, there finds its Zenith at the Beginning of the 67th Degree of Diſtance from the Equator. The Pole, elevated as many Degrees above the Horizon, carries with it the Tropic of *Cancer*, ſo far as to keep it wholly above the Horizon, or grazing the Horizon with its under Edge. As the Pole is there elevated 67 Degrees, there can remain but 23 Degrees from that to the Zenith, for compleating the Number 90 Degrees. There are from that Zenith to the Equator the 67 Degrees which ſerved me for a Rule, and from the

Equator to the other Tropic 23 Degrees, or a little more, which are in all the 90 other Degrees that reach on the oppoſite ſide as far as the Horizon. The Horizon of *Torneo* does then touch on one ſide the lower Border of the Tropic of *Cancer*, and the higheſt Point of the Tropic of *Capricorn* on the other. Thus the whole Tropic of *Cancer* is above, and the whole Tropic of *Capricorn* beneath the Horizon. In the Middle of the Summer, when the Sun deſcribes the Tropic of *Cancer*, the Day ſhall there be four and twenty Hours long. The Sun, by grazing upon the Horizon, perhaps will meet there with ſome Eminence, and poſſibly hide itſelf behind it: But it will riſe and be ſeen again an Inſtant after. On the contrary, the Sun being, on the twenty-ſecond of *December*, come to the Tropic of *Capricorn*, ſhall deſcribe a Circle, of which there will be not the leaſt Portion above the Horizon: It will therefore not be ſeen there for four and twenty Hours together: At moſt it will riſe above the Horizon with it's upper edge only, and by a few wandering Rays proclaim the Beginning of the Day; but it will immediately ſink back again into the inferior Hemiſphere; unleſs the Refractions occaſioned by the Atmoſphere, make it viſible for a few Minutes above the Horizon, while it is really under it. I no longer obſerve to you, that in all Situations of the inclined Sphere, the Equator has always one Part above the Horizon, equal to that which is under, whence comes the Univerſality of twelve Hours Day and twelve Hours Night all over the Earth, when the Sun is deſcribing the Equinoctial Line. The Reaſon of the Diviſion of the Equator into two equal Halves for all Horizons, and of the Diviſion of the parallel Circles into two unequal Portions, is grounded on the Horizon and the Equator's being two great Circles having the ſame Centre, *viz.* that of the Earth; whereas the diurnal Parallels, which the Sun deſcribes from the Equator to both Tropics, more and more recede from that Centre towards the Poles; Whence follows, that the nearer theſe Parallels draw toward the elevated Pole, the more they themſelves riſe above the Horizon, and there prolong the Day. On the contrary, the more they ſink under the Horizon towards the Pole depreſſed, the more they leſſen the Length of the Day above the ſame Horizon, while they lengthen it in the inferior Hemiſphere.

The Parallel Sphere, or the Parallel Horizon.

Now it remains, that we ſhould get under the Pole, and examine the Aſpect of the Sun, with regard to ſuch as have the Pole itſelf for their Zenith. If that Part of the World is habitable, they muſt needs have the Horizon in the Equator; for the Pole and the Zenith being the ſame thing, they both find the Equator and the Horizon at 90 Degrees Diſtance on every Side. They are united, or become parallel to each other: For which Reaſon, this Diſpoſition of the World is called the Parallel Sphere. You ſee the Conſequences of it. The Sun is ſix Months together on this ſide the Equator towards the Arctic Pole, and ſix Months on the other. If the Equator is the Horizon of the People which may dwell under the Pole, they ought to ſee the Sun going ſix Months together round them, riſing by degrees, during the firſt three Months, to the Height of twenty-three Degrees and a half, and during the other three Months, ſinking by Circles diſpoſed in the Form of ſpiral Lines; till it deſcribes on the 26th or 27th of *September*, a Parallel Circle, then beginning to recede from the Equator; and thus it alſo quits their Horizon.

But are then theſe People for ſix Months together buried in profound Darkneſs? Not at all. They enjoy a perpetual Aurora, till the Sun is fallen 18 Degrees, and perhaps more, under the Equator or Horizon, which are here but the ſame Thing. The Sun is two Months before he gets thither, and in two Months more he comes thither again, and begins a new Crepuſcle, which promiſes the Day for two Months before the riſing of the Sun. Reckoning the Crepuſcles for a Part of the Day, they are enlightened ten Months together, and during the two Months of their Night, the Moon going twice the ſame Courſe which the Sun makes in a Year, they ſee it above their Horizon two half Months of that Time: Thus they paſs no more than two Fortnights in all, in a deep Obſcurity. Nay, we may affirm from a Multitude of Accounts, that the Crepuſcles being much greater towards the Poles than in our Climates, they enjoy them even before the Sun has reached the 18th Degree from their Horizon: So that they have no Nights abſolutely dark, and even are, ſtrictly ſpeaking, of all Nations, thoſe that have the greateſt Share of the Benefit of the Light. We have at preſent no Certainty, that there are any People immediately under the Pole; ſo that we dare not affirm it: But the thing is very poſſible; and we know from the Accounts of the *Danes* and *Norwegians*, that the ſituation of the *Greenlanders*, and of many *Tartars*, who are as fond of their Country as we of ours, is pretty near the ſame as that juſt deſcribed. A nicer Reſearch would here be very needleſs. You ſee what Method is to be followed, to be certain when the Tropics are, or are not cut by the Horizontal Circle: On this Knowledge depends the ſtudy of the Length of the Days in every Country.

Now, in a few Words, let us recapitulate what relates to the Horizon. The Zenith is either in the Equator, or ſomewhere between the Equator and the Pole, or, in ſhort, the Pole itſelf is the Zenith. Thoſe who have their Zenith in the Equator ſee the Poles touching their Horizon, which, with regard to them, cuts the Equator, the Tropics, and all the diurnal Parallels into two equal Parts; whence proceeds the perpetual Equality of Days in the right Sphere.

Thoſe who have their Zenith between the Equator and the Pole, ſee their Horizon as much below the Pole, as they themſelves are diſtant from the Equator. The Equator, and all the diurnal Parallels, are inclined to that Horizon. The Equator riſes one half above, and the other is hid under the Horizon. The Tropics and the Parallels are by it cut into unequal Portions: Even ſome Parallels near the elevated Pole get entirely free from the Horizon, and the Parallels adjacent to the oppoſite Pole lie entirely hidden under it. Hence the Inequality of Days and Nights, and the perpetual Variety of thoſe Inequalities in the extenſive Length of the oblique Sphere.

Thoſe who have the Pole for their Zenith, have no other Horizon than the Equator. Thus the Sun, which dwells ſix Months on this Side the Equator, and ſix on the other, is up for ſix Months together, and lies concealed for a like Space of Time in the Parallel Sphere.

The Globe and the Sphere may ſtill, without any Application or Study, ſoon inform us of the relative Diſtances of all the People, either from Eaſt to Weſt or from North to South. The Diſtance from Eaſt to Weſt is called Longitude, becauſe the Ancients had travelled that Way more, and knew a greater Extent of Country from Eaſt to Weſt than from North to South. The Diſtance from the North to the South is called Latitude or Breadth, compared with the other Extent, which the Ancients thought was the greater; becauſe in the Times when Sciences flouriſhed in *Greece*, and ſtill more in the Time of *Ptolemy*, long after the Commerce of *Andalouſia (a)* had ceaſed by the Way of the *Red Sea*, they were generally perſuaded, that the torrid Zone was uninhabitable, and that it was ſo alſo with the cold Zones. All your Poets are full of Paſſages relating to this falſe Opinion: You know them, and therefore I ſhall not quote them to you.

Longitude, and it's Uſes.

In Imitation of *Ptolemy*, who has fixed the firſt Meridian, or the Beginning of the Longitude of Places, at the *Fortunate Iſlands*, which are our *Canaries*, becauſe they were the moſt Weſtern Lands known in his Time. The Northern Nations place the firſt Meridian in the Iſland of *Teneriffe*, one of the *Canaries*, in which the *Pico* of *Teyde* ſtands. The *French* place it in that which is called the Iſland of *Ferro*. But there is no Neceſſity of being bound to that manner of calculating Longitude; wherefore they at preſent moſt commonly reckon the Degrees of Longitude from the famous Meridian Line that paſſes through *Paris*; becauſe having been drawn with prodigious Caution, it is the moſt known Term or Point at which to begin the Account.

You have a mind to know, how much *Pekin*, the Capital of *China*, is diſtant in Longitude from *Paris*. Bring *Paris* under the common Meridian, and then remove that Point towards the Weſt, counting how many Degrees of the Equator paſs under the Meridian, till you ſee *Pekin* brought under the ſame. According to Mr. *De l' Iſle*'s great Globe, you will find 113 Degrees of the Equator intercepted, between the Meridian of *Paris* and that of *Pekin*.

The Definition of Longitude.

The Arch of the Equator intercepted between the Meridian of *Paris*, and that of any other given Place, is therefore the Longitude of that Place.

(*a*) *Tarſhiſh*.

In this Enumeration the Arctic Pole being always elevated, the Diſtance, which extends 180 Degrees to the Right, ſhews, how much any given Place is more Eaſtward than another. The Diſtance, which extends 180 Degrees on the Left of *Paris*, ſhews, how much any other given Place is more Weſtward than *Paris*. It would then be convenient to call the 180 Degrees of the Equator, which are on the Right of the Meridian of *Paris*, Eaſtern Longitude, and the other 180 Degrees, which are to the Left of the ſame Meridian, Weſtern Longitude. But as it is an univerſal Cuſtom to count one ſingle Progreſſion of Longitude up to 360 Degrees; we ſhall do the ſame whenever we have an Occaſion to mention Longitude, according to Mr. *De l'Iſle*'s Globe. The firſt Advantage the Degrees of Longitude may be of, is thereby, no doubt, to know the Diſtance from one City to another. But that ſort of Meaſure varies, and requires very great Caution. The Degrees of Longitude under the Equator, are 25 common Leagues; they are much leſs under the Tropics, and continually diminiſh toward the Pole; becauſe all the Meridians which paſs through the 360 Degrees of the Equator, all run up and unite in the Point of the Pole, and leave between themſelves Intervals always diminiſhing as they draw nearer to the Pole. If we can apply the Knowledge of Longitudes to the reducing of theſe Degrees into Leagues, it can only be by means of Tables, where the ſucceſſive Diminution of theſe Degrees as you advance towards the Pole, has been aſſigned. Here, Sir, it will be ſufficient to acquaint you, that the Degree of Longitude, which is 25 Leagues in Length under the Equator, is no more than 22 Leagues, or thereabouts, under the twentieth Degree of Diſtance from the Equator towards the Pole; 21 Leagues at the 30th Degree of Diſtance from the Equator; eighteen Leagues at the 40th; 15 at the 50th; 12 at the 60th; 9 at the 70th; 5 at the 80th; and nothing at laſt at the 90th, that is, under the Pole.

But the great Advantage we have from the Knowledge of thoſe Degrees, conſiſts in reducing them into Time. Fifteen Degrees of the Equator paſſing under the common Meridian, are equal to 60 Minutes, or an Hour, and each Degree, of courſe, is equal to four Minutes; there being four times fifteen Minutes in ſixty. The 113 Degrees of Eaſtern Longitude, which are between *Paris* and *Pekin*, may then be reduced to ſeven Hours and thirty-two Minutes; by which Diſtance *Pekin* is more Eaſtward than *Paris*. So, when the Sun riſes to us, it has already been up above ſeven Hours and a half at *Pekin*; and when it is Noon to us, it is above half an Hour after Seven in the Afternoon at *Pekin*; ſince they had Noon there above ſeven Hours and a half before. On the contrary, *Quebec* being at 307 Degrees of Longitude from the firſt Meridian, or if you will, having 73 Degrees of Weſtern Longitude, with regard to the Meridian of *Paris*; the Sun will not riſe at *Quebec*, till five Hours wanting eight Minutes after it has riſen at *Paris*; and when it is twelve o'Clock at *Paris*, it is hardly a Quarter after ſeven in the Morning at *Quebec*.

The Definition and Uſes of the Latitude.

The Latitude of a Place is its Diſtance from the Equator towards either of the Poles; and it being reckoned on the Meridian, we may define it to be the Arch of the Meridian intercepted between the Equator and any given Place. For Inſtance, to find the Latitude of *Paris* or of *London*, you muſt alternately bring theſe two Places under the Meridian, and from the Equator to *Paris* you will reckon 49 Degrees, and to *London* 51 $\frac{1}{2}$.

The Advantage of this Knowledge is, firſt, that we may reduce into common Leagues, of which there are 25 to each Degree, the Diſtances which are from the Equator to the Pole. We enter not here upon the Queſtion of the Extenſion or Flattening of the Earth towards the Poles, which may occaſion no great Difference, if the Earth be not entirely round. Secondly, The Knowledge of the Latitude puts us in a Way to mount the Globe horizontally for any particular Place, that is, to determine the Horizon of it, in order to anſwer the Queſtions that may be made concerning the actual time of Day, the riſing or ſetting of the Sun in that Horizon on ſuch a Day of the Year, and the Duration of the Days, Nights, and Crepuſcles.

They enquire, for Inſtance, what o'Clock it is at *Torneo* in *Lapland*, when it is twelve o'Clock at *Paris* this 10th of *May* 1737. After having faſtened the little horary Circle with its Hand on the Meridian, I bring *Torneo* under the Meridian; and finding it to have 67 Degrees of Latitude, I give the Pole an Elevation of a like Number of Degrees. I look out in the Kalendar of the Horizon for the 10th of *May*, and find that it correſponds to the 19th Degree of *Leo*. I clap on the 19th Degree of *Leo* in the Ecliptic, a very ſmall Patch of white Paper; or if I don't care to daub any thing, I bring under the Meridian the ſame Point of the Heaven, which I take great Care to remark, and under which the Sun is actually placed. If after having applied the horary Hand on the Point of Mid-day, that is, on the uppermoſt of the two Figures marked XII. I cauſe the Globe to turn back towards the Eaſt; and the Moment when the 19th Degree of *Leo* touches the Horizon, the Hand will point at half an Hour after two for the riſing of the Sun above that Horizon. The ſame Point carried thence to the Meridian, and from the Meridian to the Weſtern Border of the Horizon, will mark out the Path or diurnal Arch of the Sun over the Horizon of *Torneo*. The Horary Style will point at half an Hour after Nine, the Moment the 19th Degree of *Taurus* ſinks under the Horizon. Thus I am preſently informed, that the Duration of the Day on the 10th of *May*, is 19 Hours, and that of the Night five Hours at *Torneo*; if we may call that Night, when the Sun obliquely going down, ſinks but three Degrees under the Horizon.

It is required, what the Aſpect of the Heaven and the Duration of the Day will be for the ſame Place, on the 8th of *December*. I look for the 8th of *December* in the Kalendar on the Horizon, where it correſponds to the 16th Degree of *Sagittary*. That Degree being brought under the Meridian, and the Hand placed at Noon, if you then turn the Globe ſo as to make the 16th Degree of *Sagittary* juſt appear above the Eaſtern Part of the Horizon; you will find the Hand pointing to half an Hour after Eleven, the very Inſtant the Sun or the ſaid 16th Degree ſhall get above the Horzon: And when it ſhall paſs under the other Edge thereof Weſtward, you will find the Hand at half an Hour after Twelve. Therefore the Day is but an Hour, and the Night 23 Hours long on the 8th of *December* at *Torneo*.

To the Advantage of knowing the Elevation of the Pole, and of finding the Horizon of a Place, by the Knowledge of its Latitude, let us add that of knowing the Elevation of the Equator, for the Horizon of the ſame Place.

When the Globe is horizontally mounted for *Paris*, you have 49 Degrees Diſtance between the Pole and the Horizon, juſt as you have them in Latitude between the Equator and the Zenith. Now from the Zenith to the Horizon there are but 90 Degrees on every Side. If from theſe 90 you take the 49 of Latitude, there remains 41, which Number expreſſes the Height of the Equator above the Horizon of *Paris*. The Height of the Equator above the Horizon, is then the Difference between the Number of the Degrees of the Elevation of the Pole, and 90 Degrees.

By this Means you know, that on the 21ſt of *March*, and the 23d of *September*, the Sun, which then deſcribes the Equator, at Noon obtains the Elevation of 41 Degrees above the Horizon of *Paris*. Add thereto the twenty-three Degrees and a half of Declination, or of a greater Elevation towards the Arctic Pole, you will have 64 Degrees and a half for the Elevation of the Sun at Noon, on the 22d of *June*, that is, the Day of the Solſtice. From the 41 Degrees, which is the mean Height, or that of the Equator, take the like Sum of 23 Degrees and a half, you will find 17 Degrees and a half for the Elevation of the Sun at Noon, on the Day of the Winter-Solſtice at *Paris*. You may with like Eaſe know the exact Height of the Sun at Noon, for any Day of the Year whatever. For if after having found in the Ecliptic the Place or Degree of the Sun for any given Day, you bring that Degree under the Meridian, you ſee by how much the Sun declines from the Equator, either on this Side towards the oppoſite Pole, or on the other Side towards the oppoſite Pole. If it be on this Side in the Northern Signs, add the Declination to the Height of the Equator, you will have the Elevation of the Sun at Noon for the given Day. If the Sun is in the Southern Signs, deduct its Declination from the Height of the Equator above the Horizon.

Hence follows, that whoever knows the Latitude, knows the Elevation of the Pole, whoſe Meaſure is the ſame: That whoever knows the Elevation of the Pole, knows likewiſe that of the Equator, which is always the Complement or the Difference between the Height of the Pole and 90 Degrees: Laſtly, That he who knows the Elevation of the Equator, knows alſo the Elevation of the Sun at Noon for all the Days of the Year, by the Addition or Subſtraction of its Declination.

Globes are of Service in a hundred other Particulars, of which we muſt defer the Enumeration to a Treatiſe of Aſtronomical Inſtruments, which I hope hereafter to give you. It was proper at leaſt, to give you this faithful Account of the moſt common Helps which we borrow from thence, in order to convince you of the Favours, for which we are beholden to the Learned of *Greece*, and to Natural Philoſophy, which has founded theſe wonderful Machines on the Obſervations of the Rotundity of the Earth, on the Obſervations of the Points which bound the Courſe of the Sun, on the regular Obſervations of the ſeveral Horizons, and the various Elevations of the Pole; in ſhort, on a Series of inconteſted Experiments.

The Mariner's COMPASS.

THE DISCOVERY OF THE *Eaſt* and *Weſt-Indies.*

The REVIVAL *of* SCIENCES.

DIALOGUE V.

EVER ſince the Time of *Pliny* and *Ptolemy*, Coſmography and the Study of Nature, far from makin any new Progreſs, diminiſhed by degrees, and remaine totally neglected. In the firſt Ages of the Church, th moſt knowing Chriſtians were too much taken up wit the Care of inſtructing Nations, and of ſupporting th Goſpel againſt the Heathens, to be able to give themſelve over to Studies either leſs neceſſary, or leſs importan After having deſtroyed Idolatry, they turned their Arm againſt the Diſturbers of the Church, who introduced pernicious Novelties into the Faith. On the other hand, the Liberty which the *Roman* Armies aſſumed to themſelves of creating ſeveral Emperors at the ſame Time, and the inteſtine Diviſions of the Provinces, which took the Party of

one Emperor againſt another, put all in a Combuſtion, and ſhook the whole Empire. The perpetual Attempts of the Barbarian Nations to ſhake off the Yoke, reduced the Eaſtern Empire within very narrow Bounds, and quite overthrew the Weſtern. After its Fall, the State of *Europe* was long uncertain, and had much ado to preſerve one conſtant Form. The frequent Changes of Maſters, Laws, Languages and Cuſtoms, kept Nations in a kind of Agitation fatal to Sciences and good Taſte, which were ſucceeded by Barbarity and Ignorance.

Afterwards, the Introduction of great Fiefs and Sovereignties ſubordinate *in infinitum*, held by Fealty and Homage, or with an Obligation of a ſhort Service, finiſhed the Ruin of all. This Form of Government, wherein they fancied they ſhould find a greater Appearance of Liberty and Security, made its Way every where, and multiplied Feuds, together with the Affectation of Independence. There was not a Country Squire, how inſignificant ſoever, that did not lord it, and play the Monarch among his Vaſſals, and lead them to War againſt his Neighbours. This Liberty of drawing the Sword in ones own Cauſe, and of doing ones ſelf Juſtice between Lord and Lord, together with the unavoidable Wars of the Lords-paramount, turn'd every Mind to War. The wearing of the Sword being thus become the diſtinctive Badge of Lordſhip, Lords were no longer ſeen without it. This Inſtrument of Wrath accompanied them to their beſt Friends. They were ſeen armed even at the public Prayers; and when they united the Title of Biſhops to that of Lords, their Swords appeared on the Altar together with the Victim of Peace. The Uſe of the Sword, by Right reſiding in the Chief of the State alone, who held it from God, had till then been only precarious and temporary in the Hand of Subjects. That Right, or rather that Commiſſion, was transferrable from one Man to another, at the Prince's Will. The Uſe of it was never given over to the Diſpoſal of any private Man, but only entruſted and regulated according to the Wants of the State only. The firſt Officers had no more the Poperty or Inheritance of it than our common Soldiers. Since that Right, originally derived from the Throne, was given in Property as an hereditary Good to a Multitude of Subjects,

and

and was extended to the Subdiviſions of the remoteſt Meſne Tenures; this Appearance of petty Sovereignty became the Object of all Wiſhes. Nothing was thought grand but the Sword: It was in lieu of Learning and Education: It even became the only Science: And for want, not only of Books, but eſpecially of Tranquillity, Emulation, Applauſe, and good Examples, Ignorance in all its Branches overſpread the World in the moſt diſmal manner. The liberal Arts and Literature, Eloquence, and the Study of Nature, which had, by the Care of *Charlemagne* and his Succeſſors, reſumed a little Courage, ſunk again into a Condition worſe than that to which they had been already reduced, By the Barbarity of the *Goths* and other Northern Nations [*].

'Tis true, Churchmen, and ſome learned Princes, from time to time made uſeful Efforts towards reviving the Love of Letters. For many Ages together, the holy Precepts of the Church, a few Collections of the nobleſt Sayings of the Fathers, which were read to the People, and the reading of the Goſpel, maintained Faith in its Purity, and preſerved the Principles of Integrity among Men: But a falſe Learning, in ſome ſort worſe than Ignorance, came acroſs the beſt Intentions, and ruined the Benefit of the beſt Eſtabliſhments.

About the middle Ages, a kind of Learning of a moſt ſingular Character overſpread all *Europe*. Though they had in their Hands the Writings of the *Latins* and *Greeks*, which the *Benedictine* Monks had taken care to copy and multiply; they neglected the Uſe of the Orators, Poets, and Hiſtorians, to exerciſe themſelves merely in *Ariſtotle*'s Philoſophy; in which too they laid aſide whatever related to the Heaven, the Knowledge of our Globe, Natural Hiſtory, Eloquence, and that of Mankind. This Part (for what Reaſon I know not) did not pleaſe them at all: But they gave themſelves paſſionately over to his Logic and Metaphyſics. Theſe cavilling Sciences very likely had an intimate Proportion with their natural Craft and Subtlety. Beſides, they needed not, in order to attain them, to make any Re-ſearches, great Enquiries or Trials, to keep any Correſpondences; to have any Books or Inſtruments; to uſe Calculations, or give themſelves any Trouble. They were extremely pleaſed with the Thoughts of finding out every thing in their own Brains, and of acquiring without any Preparatives, and at no Coſt, a vaſt Reputation for Subtlety and profound Learning by bandying Queſtions, of which the common run of Mankind could underſtand nothing.

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[*] See Mr. *Fleury*. See the Abbot *Goujet*'s Diſſertation on the State of Sciences in *France*, &c.

Theſe Philoſophers of the middle Age did, indeed, ſpeak upon every Subject: They even thought themſelves great Men in Phyſics, becauſe they gave Names to, and Definitions of, every thing, by methodically proceeding therein with the Genus and the Difference. They eſpecially pretended to teach Men how to argue, and this was their chief Skill. Had it not been for their Rules, all Mankind was ready to fall again into its primitive Infancy. But their Categories, their Dialectic, and the ſubtle Anatomy they made of our Ideas, Judgments, and Reaſonings, and of the ſeveral Pieces whereof our Diſcourſes conſiſt, were not much more fit to teach us the Art of Thinking, than the Anatomy of the Hand, or the Study of the Muſcles of the Leg would be, to teach us how to make the Rigadoon-ſtep, or how to handle a Fork with a good Grace. Poor Doctors! who attributed to their Art that which is in Man a Gift from God, and who, by Force as it were of Machines, cauſed ſome Men to do with a dull and heavy Aukwardneſs, what Exerciſe and Reflexions every where produce with ſo much Elegance, Exactneſs and Facility.

The ſame Idleneſs which made them prefer theſe empty Speculations to long and toilſome Experiments, likewiſe made them overlook the Study of Elocution. They even neglected the Decorum of Speech. But Barbarity, which is ever attended with Diſguſt, is ſtill the leaſt Evil they overſpread the Schools with. They accuſtomed Men to diſpute, and of courſe to the Deſire of being always victorious in the Argument: An Exerciſe which was apt to become dangerous, if not moderated with a great Politeneſs, which, under the Pretence of rendering the Learned methodical, made them apt to ſtart Difficulties on every Subject, eager to reply, and become in a manner People of another World; who, inſtead of ſound and ſerviceable

Truths, gave them no Reliſh for any thing but Subterfuges, Subtleties, and puzzling or rather inacceſſible Queſtions; which far from making them humble, modeſt, pliant, ready to liſten to and aſſiſt others, on the contrary made them fond of their own Conceits, always ready to combat the Talents of others, and made them little better than idle Talkers, Men univerſally inept when out of a Diſpute; and by an almoſt neceſſary Conſequence, fierce, poſitive, and untractable.

Theſe new Maſters, by the Oddneſs of their Queſtions, and by the Sourneſs of their baſe contentious Method, diſhonoured the Schools which they had invaded. They every where introduced a dark grim kind of Learning, that related to none of thoſe Things which buſy Mankind; that was of Service to no Condition of Life, and which having no manner of Relation to Piety, to Buſineſs, to the Sentiments of the Heart, or to Politeneſs, authorized the genteel Part of the World, not only to forſake them without Regret, but even to bluſh at being thought to have the leaſt Tincture of Learning.

The Knowledge you have of Hiſtory, my dear *Chevalier*, makes you eaſily gueſs, that the rough, ſupercilious Philoſophers I juſt mentioned, are the *Arabians*, who overſpread the Coaſts of *Languedoc*, *Italy*, *Sicily*, *Spain*, and *Afric*. The School which they eſtabliſhed at *Cordova*, in the Kingdom of *Naples*, and other Places, took an Air of being famous, while ours were in a languiſhing State. What contributed moſt to the Barbarity of the Method of the *Saracens*, was, that they had it for a Rule to neglect the good Authors of *Rome* and *Athens*, which they every where found in our Libraries, thinking, that the reading of theſe Books, wherein the Names of the Gods were often found, was inconſiſtent with the Law of *Mahomet*, which they profeſſed: And either from a Motive of Religion, or by their own Taſte, they confined themſelves to the moſt bombaſtic, moſt ſpeculative and leſs uſeful Works of *Ariſtotle*'s. The *Latin* Tranſlations, and numerous Comments which they publiſhed of them, ſpread their Notions and Methods among us: And having ſince been obliged to abandon all their Poſts one after another, to leave *Europe*, and ſhelter themſelves in *Mauritania*, they did not carry away all their Subtleties and imaginary Tenets with them. They went to make uſe of them in the Schools of *Fez* and *Morocco:* But they left among us the Dregs of a falſe Learning, a Philoſophy wholly intellectual, which ſeemed to have forgot, that we had Eyes to ſee, and Hands to operate. A Method the more contrary to the Advancement of Phyſics and Diſcoveries, becauſe inſtead of regulating its Notions and Experience, and on the perpetual Inſpection of Nature, it judged of every thing from the Notions of old *Ariſtotle*, or of ſome other Maſter as little to be depended upon, though of a more modern Date. So long as our old Scholaſtics quarrelled, without ever looking in Experience for a Solution of their Diſputes, Philoſophy made no real Progreſs, except under the Trials of ſome Workmen. The Neceſſity of fining Metals for the coining of Money, the caſting of Bells and Ordnance, for Goldſmiths Ware and the Products of the Forges, and for the making of ſeveral Kitchin-Utenſils, at all Times put a certain Number of Men under the Neceſſity of acquainting themſelves, if not with the Nature, at leaſt with the Uſe of the ſeveral Earths, and of all mineral Matters. It may be affirmed, that uſeful Learning was almoſt wholly centred among Artificers in Metal, who for want of a Guide, and of good Principles, very often ran headlong into the groſſeſt Miſtakes. For Inſtance, the Sight of the apparent Changes which happened in theſe Matters, either diſunited or compounded, had long introduced this falſe Notion, that Natures, even the moſt pure and uncompounded, are tranſmutable, and that a Piece of Iron may, by Means of a certain Preparation, become an Ingot of Gold. Many Artiſts, building on this falſe Principle, in all Ages, made ſeveral Efforts, the vaſt Expence and Inutility of which loaded them with Shame, and both exhauſted their Health and Money. However, many of them, as they were working in theſe foſſil and mineral Matters, which obſtinately refuſed the Tranſmutation ſo much longed for, by the by, took Notice of the new Effects produced, and hit upon ſome conſtant Compoſitions, which might be made uſeful to Dying, to Metal-working, and the Improvement of a great many Arts. They indeed hunted after a Phantom, but yet they operated at the ſame Time. They traced

Nature Step by Step; and this was ſufficient to make them find out real Truths and Conveniencies, which ſometimes made them Amends for the imaginary Tranſmutation they flattered themſelves with.

The moſt ſucceſsful among them was *Roger Bacon*, an *Engliſh* Cordelier *. He firſt knew the Force of Sulphur and Fire in Conjunction with Saltpetre or Tartar, which gave Birth to Gunpowder, and occaſioned the Perfection of Fire-Arms. He ſeems to have been one of the firſt, who had any juſt Knowledge of the Effects of Light conveyed through a lenticular Glaſs, or reflected from a ſmooth Surface either plain or concave. His Philoſophy wholly conſiſted in obſerving Nature, and making uſe of it, by the Aſſiſtance of Mathematics. He was in the right way, and invited every body to follow him therein. But his Superiors, Maſters and Fellow-Monks, ſtyled thoſe dangerous Novelties, which they had not learned themſelves. He perhaps gave them Offence by ſuperſtitious Practices, as he was extremely bigotted to celeſtial Influences, and all the Nonſenſe of Judicial Aſtrology. The Studies to be followed, moreover, and the Opinions to be maintained, either in Monaſtic and Eccleſiaſtic Societies, or in Univerſities, were preſcribed as well as the Ceremonial or the Hour of getting up and going to Bed. Nothing but ill Uſage was to be expected by any that ſhould preſume to abandon *Ariſtotle*; and the general fixed Rule left no room, either for Re-ſearches, or any Diſcoveries. The Philoſophy of the *Arabians*, and their tireſome Jargon, remained in Poſſeſſion of the Schools. Univerſities have, till the very laſt Century, heſitated upon having Recourſe to Knowledge grounded on Experience, and juſtified by Practice. In Convents very often, where Philoſophical Studies were purſued, the Reader proved much leſs ſkilled in ſound Philoſophy, than the Brother who prepared the Remedies, or took care of the Kitchen-Garden. Even now in ſeveral provincial Schools, if they employ three or four Hours in curſorily ſhewing a few Experiments on *Vacuum* and the Elaſticity of the Air, they in return employ ſeven or eight entire Months, in leiſurely treating of Matter and Form, never forgetting

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* Died at *Oxford* in the Year 1284.

Privation, nor ſubſtantial Form, nor the Appetency of Matter for all Forms, nor chiefly the modal Interceſſion, as a diſtinct Entity between Matter and ſubſtantial Form.

Though the *Arabians* did thus very much injure Mankind, by rendering Knowledge hateful on account of the Barbarouſneſs of the Language, and eſpecially by ſmothering, for ſeveral Centuries together, the nobleſt Talents and the beſt Genius, by an Habit of always exerciſing them upon idle Notions, which could be of no Uſe in the World; yet muſt we not refuſe to give a few of theſe *Saracen* Doctors their Due. Some of them raiſed themſelves above the common Level, by purſuing uſeful Studies. Some applied themſelves to Phyſic, and that Study has, after their Retreat, perpetuated itſelf in more than one of their Poſts; for Inſtance, at *Salerno* in the Kingdom of *Naples*, and with far greater Succeſs at *Montpelier*; which was raiſed upon the Ruins of *Maguelona*, one of their beſt Eſtabliſhments. We are beholden to the *Arabians*, for the Figures of our modern Arithmetic and the Uſe of *Algebra*, if they be not even the Inventors of the latter. Some of them, careſs'd and made much of by the *Egyptian* and *Babylonian* Caliphs, cultivated Aſtronomy, meaſured the Circuit of the Earth, tranſlated into their own Language, and communicated to *Europe*, *Ptolemy*'s Books *, together with the Uſe of the Aſtrolabe or flat Sphere, and of ſeveral other very ingenious Machines, all the Pieces whereof ſtill go by *Arabian* Names, though they only ſhewed the Uſe of them, and the Invention was due to the *Greeks*.

The Emperor *Frederic* II, in the XIIIth Century, cauſed *Ptolemy*'s great Conſtruction to be tranſlated from the *Arabian* into *Latin*: Which enabled a Profeſſor † of the Univerſity of *Paris*, to write a Work which was much admired and made uſe of every where upon the Sphere. *Alphonſo*, King of *Caſtile* ‡, employed ſeveral learned Men in reforming Aſtronomy, and became himſelf a very good Aſtronomer. In the next Century, *Charles*, ſurnamed *the Wiſe*, though wholly taken up with a much more neceſſary Science, I mean the Government of his

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* In the Year 813.

† *Sacro Boſco*, a Mathurine Friar, who died in the Year 1256.

‡ In the Year 1270.

Kingdom, perſuaded *Piſan* of *Boulogne* to come to *Paris*, rewarded generouſly the Works of *Nicolas Oreſme*, and founded ſeveral Profeſſorſhips for Mathematics *. But theſe ſolid Studies ſupplying no Matter for Diſpute, which was then the reigning Taſte, they were always very languidly purſued; and, what was ſtill worſe, the *Saracens*, who had introduced them to us, had mixed them with all the Poiſon of Aſtrology; ſo that their Acquaintance was hurtful to us in all reſpects.

While the fineſt Genius's exerciſed themſelves pitifully on Generalities, that were of no ſort of Service to the Pulpit, the Bar, the Government of States, nor even to the Wants of Families; a kind of Hazard, or rather a ſpecial Providence, cauſed a Phænomenon to be obſerved, the Diſcovery of which has procured us the Knowledge of a new World, the new Way to the *Indies*, and ſuch a Progreſs of Sciences, as was yet never attained by them.

The Sea Compaſs.

The Load-ſtone, in all Ages, was known to have had the Property of attracting Iron. *Thales*, amazed at ſo conſtant an Effect, thought that Stone had a Soul. *Plato*, *Ariſtotle*, and *Pliny*, have mentioned the ſame Attraction: But neither they, or any other Philoſophers, till the XIth, or even to the Beginning of the XIIth Century, knew, that the Load-ſtone ſuſpended, or ſwimming by means of a Piece of Cork on Water, always turns one of its Sides, and conſtantly the ſame, towards the North. Even the Man who made this Obſervation ſtopped there, and underſtood neither the Importance or the Uſe of his admirable Diſcovery.

Theſe two Properties of attracting Iron, and of being conſtantly directed Northward, being once known; ſome Virtuoſo's repeated the Experiments; and making a Piece of Iron and a Load-ſtone to ſwim in a Veſſel full of Water (having firſt put them on Pieces of Cork, that they might move one towards another without any Obſtacle) they obſerved, that when the Piece of Iron had been rubbed againſt the Load-ſtone, that Iron had alſo the Property of turning towards the North, and of attracting Needles and Iron-filings, as well as the Load-ſtone itſelf. From one Experiment to another, they came to lay a Needle touched with the Load-ſtone on two ſmall bits of Straw floating on the Water, and to obſerve, the Needle invariably turned it's Point towards the North. They were in the way of making the great Diſcovery: But this was not yet what we call the Sea Compaſs.

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* At the College of *Maitre Gervais.*

The firſt Uſe which Virtuoſo's made of this Diſcovery, was, to impoſe upon ſimple People, by an Appearance of Magic. For Inſtance; a little hollow Swan of Enamel, ſwimming by that Means on the Water of a Veſſel in which it was put, and having in his Bill a little Iron Serpent or Lizard, never failed to run after a Piece of Bread offered him on the Point of a Knife: It faithfully followed the Motions of the Knife backward and forward, and gave the utmoſt Surprize to the Spectators, who were ignorant, that the Knife had, by the Touch of the Load-ſtone, acquired the Property of attracting Iron. The pretended Magician fully convinced them of his Power, by ordering a Needle laid on the Surface of the Water, to turn its Point from the Eaſt to the South, and bring it towards ſuch or ſuch a Point, as towards the Polar Star; which was immediately obeyed.

A Genius of a more ſerious Turn, at laſt applied this Experiment to the Wants of Navigation, and a Poet * of the XIIth Century informs us, that our *French* Pilots made uſe of a Needle touched with the Load-ſtone, which they called † *La Marinette*; becauſe that Stone being ſeveral Times rubbed the ſame Way, and on the ſame Side, upon an Iron Needle, communicated thereto the Virtue of turning towards the unmoveable Star, which we call the Polar Star, and which was a Rule for Seamen in cloudy Weather.

Icelle étoile ne ſe muet,
Un art font qui mentir ne puet,

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* *Guyot* of *Provins*, who was at the Court of the Emperor *Frederic*, held at *Mentz*, in the Year 1181.

† See Abbot *Urſperg* and *Faucbet*'s Antiquit.

Par vertu de la Marinette,
Une pierre laide, noirette,
Où li fer volentiers ſe joint, &c.

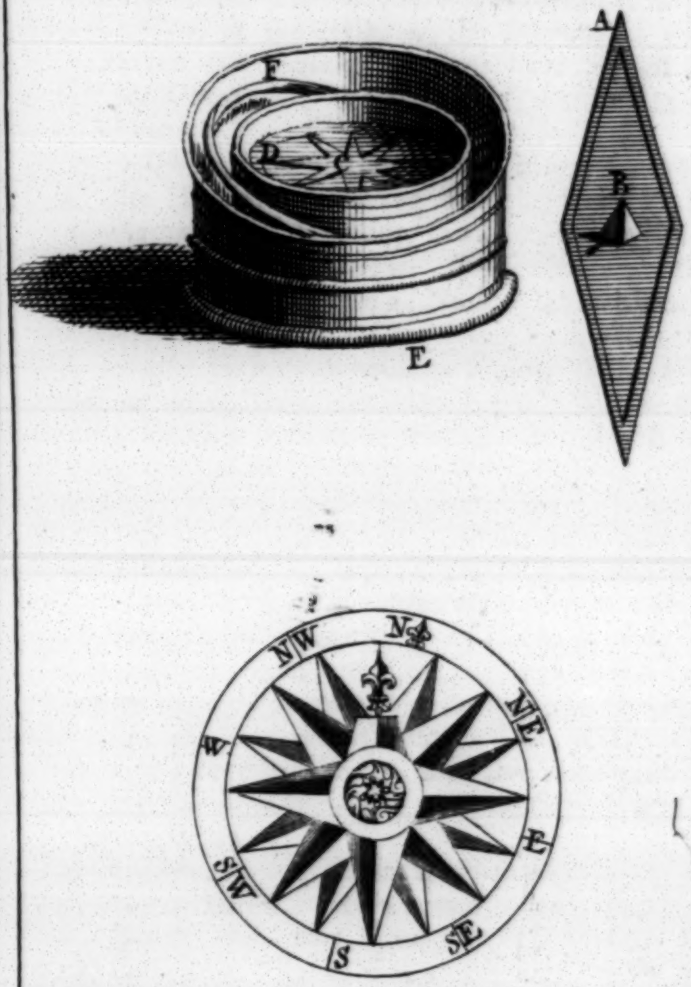
Soon after, inſtead of laying the Needles (as they did then) upon Straw, or a Piece of Cork, on the Surface of the Water, which the Motion of the Veſſel always toſſed immoderately; an underſtanding Workman bethought himſelf, of ſuſpending on a Pivot, or on a moveable Point, the juſt Middle of a Hand touched with the Load ſtone, that ballancing and playing at Liberty, it might yield to the Attraction, which always directs it towards the Pole. At length, another Workman thought of charging that Needle with a ſmall and very light Circle of Paſte-board, whereon he had delineated the four Cardinal Points, together with Lines repreſenting the chief Winds: The whole being divided into the 360 Degrees of the Horizon. This little Machine lightly ſuſpended in a Box, which was itſelf ſuſpended much like the Seaman's Lamp, perfectly anſwer'd the Hopes of the Inventor; becauſe, by directing the *Fleur-de-lis* towards the North, it kept all the other Points of the Roſe correſpondent to the Points of the World by them repreſented. And though the Veſſel might have changed its Situation ever ſo much, yet the Needle, conſtant in its Return towards the North, always ſhewed by the Points of the delineated Figure, the Part of the World towards which they ſailed, and the Winds they were to avoid.

But it is with this Invention, as with that of Mills, of Clocks, and the Art of Printing. The Name of the Inventor is not known, becauſe many had Share in the Diſcovery. Theſe Things were found out only in Parts, and gradually brought to a greater Degree of Perfection.

From this it is plain, what we are to think of the Diſpute ſtill ſubſiſting between ſeveral Nations which claim the Invention of the Sea Compaſs. The *Italians* are poſitive, that in the Year 1302, *Flavio Gioia* conſtructed the very firſt Sea Compaſs that was ever ſeen, at *Melphi* in the Kingdom of *Naples*. The *French* are very far from ſubmitting to this Judgment. They ſay, that the Uſe of the Needle rubbed with the Load-ſtone, for the regulating of Navigation, is from Hiſtory proved

Plate 19 Vol. IV. Pag. 256.

The Sea-compaſs.



A. The needle touched with y^e load-ſtone, upon w^{ch} y^e Card of y^e winds is faſtened. B. The concave Cap to Suspend y^e Needle upon a Pivot, w^{ch} Stands at Bottom of a leaden cap. C. The Card of y^e Winds. D. The horizontal Border w^{ch} changes its Situation as y^e Ship changes hers, whilst y^e Needle remains fixed to y^e North. E The Box. F Several circles Suspended one within another; upon pivots that croſs each other. The innermost is horizontally fixed by a leaden-Cap that weighs downwards.

Toms Sc.

to have been among them even in the XII^th Century. They add, that if a *Fleur-de lis* is for a Mark of the North, either in the moveable Paſte-board, which Seamen put in the Style, or in the Card of the Winds, which is faſtened under the Pivot of the Style, at the Bottom of fixed Sea-Compaſſes; it is becauſe all Nations have copied it from the firſt Sea-Compaſſes, which came from the Hands of a *French* Artificer.

The *Engliſh* attribute to themſelves, if not the Diſcovery, at leaſt the Honour of having brought it to Perfection, by the Method of ſuſpending the Box where the Needle touched with the Load-ſtone is. They alledge in their own Behalf, that it is from them all Nations received the Names given the Sea-Compaſs, on receiving from them that Machine, reduced to a commodious Form: That it is called (*Compas de Mer*) from the two *Engliſh* Words *Mariner's Compaſs*; and that from their Word *Boxel*, which means a little Box, the *Italians* made their Word *Boſſola*; juſt as they change the Name of *Alexander* into that of *Aleſſandro*.

Others are no leſs zealous to perſuade us to give the *Chineſe* the Honour of it. But as the Needle touched with the Load-ſtone, is as yet no otherwiſe uſed in *China*, than as it is made to ſwim on a Piece of Cork, as they formerly did in *Europe*; it may be thought, that *Marco Paolo*, or ſome other of the *Venetians* * who went to the *Indies* and *China* through the *Red Sea*, did, in the XIII^th Century, convey to the very Bottom of *Aſia* this important Experiment; the Uſe of which was afterwards perfected among us by ſeveral Pilots.

The Declination and Inclination of the Needle.

The Needle rubbed with the Load-ſtone, beſides its conſtant Direction towards the North, has yet two other Motions: The one of *Declination*, by which it deviates a few Degrees from the true Meridian, or from the Shadow of the Sun at Noon: The other of *Inclination*, by which it lowers towards the Earth its Northern Point; as if that Point was heavier when rubbed with the Load ſtone, which obliges us to charge the Southern End of the Needle with more Weight, in order to keep it Horizontal, and in a perfect Equilibrium.

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* See *Orbis novus*.

From the Knowledge of the Quantity of that Declination, which is much the ſame from Year to Year, and ſometimes for many Years together, they take all previous Cautions, to have it adjuſted as if it did not decline at all. As to the Inclination, though the Knowledge of it has been hitherto unfruitful; we ſtill hope, that the Regularity of it will one Day or other be applied to ſome profitable Uſe.

The beſt Conjectures that at preſent may be had on the Cauſe of the Directions of the Needle.

Great Naturaliſts are much divided, on the Cauſes of theſe ſeveral Directions of the Load-ſtone. But there is a Truth infinitely more obvious to me than all their Syſtems, *viz.* That God has freed us of a very great Care, and ſaved us many dangerous Inadvertencies, by granting us the Uſe of Things, without letting us into the Structure and Reaſons of the ſame.

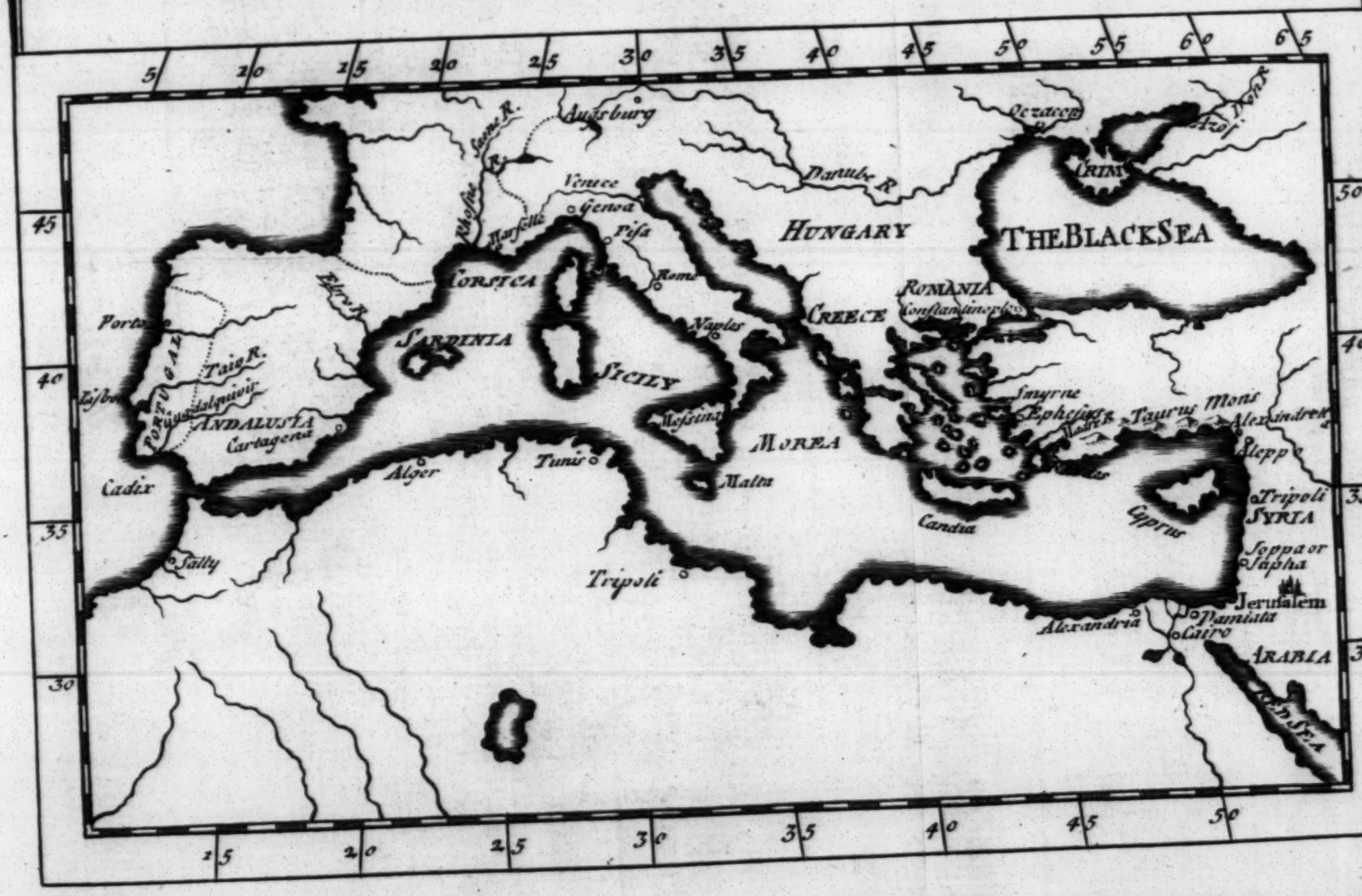
We are ignorant of the Cauſe of the Direction of the Load-ſtone, as we are of the Bottom of whole Nature: But we know the Uſes to which they may be applied, and that Science is of more Advantage to us, than the Knowledge of the Cauſe itſelf. The Knowledge of Cauſes would make unactive Philoſophers, who could never be brought from their ſublime Speculations to the Government of Things here below. The bare Knowledge of the Directions of the Load-ſtone, carries us from one End of the Earth to the other. A Sea-Compaſs worth half a Crown, may bring into our Ports the Productions of the four Quarters of the World. And it is really from this Invention, brought to its Perfection in the XIVth Century, that we may date the Renewal of Geography, Trade, Natural Hiſtory, and true Phyſics.

The ancient Commerce of *Europe*.

The Pilots of *Marſeilles* and *Piſa*, the *Genoeſe*, and the *Venetians*, by the Aſſiſtance of this admirable Inſtrument, in the XIVth and XVth Centuries, carried on a very profitable Trade at *Tripoli* in *Barbary*, at *Japha*, at *Damas*, by the Way of *Tripoli*, in *Syria*; at *Aleppo* by the Way of *Alexandretta*, at *Famagouſte* in *Cyprus*, at *Smyrna*, and in all the Sea Ports in the *Levant*; whence they returned, and ſpread all over *Europe*.

Cotton,

THE CIRCUIT
# of the
MEDITERRANEAN SEA.



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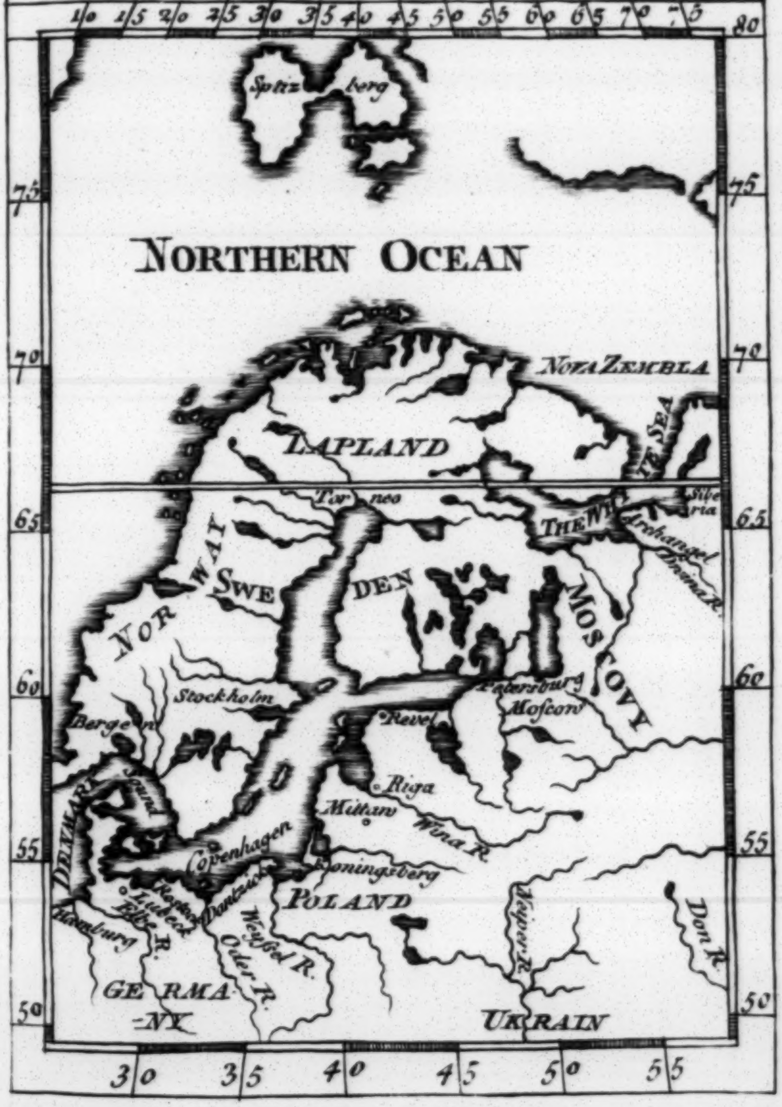
THE NAVIGATION of the NORTH



Cotton, Opium, Rice, Gall-nuts, Drugs, and the other Commodities of *Aſia*.

The Commerce of the *Hans Towns.*

The Uſe of the Sea-Compaſs rendered all the Enterpriſes of the Merchants of *Berghen* in *Norway*, of *Stockholm*, *Riga*, *Dantzic*, *Roſtoc*, *Lubec*, *Bremen*, *Hamburgh*, and of all the great *Hans* or Aſſociation, which was formed for the Commerce of the *Baltic Sea*, and of all the North. But the fineſt Trade of thoſe Times, was that which the *Venetians* had at *Alexandria* and *Cairo*, of the Commodities which the *Arabians* and *Egyptians* fetched from the *Indies*, and from all the Eaſt through the *Red-Sea*. The Profits they made on their Cotton, Silk, Gold, Pearls, and Jewels, were immenſe: But Spices and Grocery Wares were the fineſt Branch of their Commerce. They were the only Diſtributers of them; and at that Time, no Dainty was thought, at the niceſt Tables, ſuperior to that Production of *Indus* and the *Molucca Iſlands.* Sugar was little or ſcarcely known at all in *Europe:* But Spices began to be there the chief Ornament of great Feaſts. They thought nothing was fitter to be preſented to Judges after the Deciſion of a Law-Suit. At Nuptial Feaſts the Bride diſtributed Spices to all the Aſſembly; and Univerſities, in their Rejoicings, had in this conformed to the Uſe of the *Beau Monde*. That Commodity always went off very well, and every one knows how far the Art of Cookery has carried the Uſe of them.

The Commerce of *Venice* and *Cairo.*

The Proſperity of the *Venetians* awakened the Emulation of the Inhabitants of the Coaſts of the Ocean. Moſt of them made Attempts, either themſelves to reach the *Indies*, or to diſcover ſome new Coaſts, where they might trade with Profit. The Facility of avoiding the Shelves and Shallows by taking Sea-room, and of finding their Way in again by the Direction and Advices of the Sea-Compaſs, filled theſe two Ages with extraordinary Adventures, and with Diſcoveries more lucky than were expected.

The Diſcoveries of the *Normans.*

The *Normans*, a laborious and perſevering Nation, and capable of every Thing, were the firſt who diſcovered

Guinea, and the *Canary Iſlands*, the Remembrance of which had been a long time loſt. We ſtill find in *Guinea* the little *Dieppe*, where the Inhabitants of *Dieppe* had lodged themſelves, from the Year 1364, and ſeveral other Names teſtify the ancient Settlements of the *French* on the Weſtern Coaſts of *Africa*. They abandoned them in the Year 1410: But the Natives preſerve the Memory of them, and ſtill regret the Sweetneſs of their Commerce. Theſe Settlements would ſtill have ſubſiſted, or have been renewed and embelliſhed, had the Government aſſiſted them, and preferred, as now they do, true Politics, which are the important Affairs of the Commerce and Repoſe of the Nation, to thoſe brilant and ſhewy Intrigues which make the People miſerable, in order to give them a Proof of the Miniſter's Capacity.

The Ivory, which the Inhabitants of *Dieppe* brought from the Tooth-Coaſt, gave Birth to the Eſtabliſhment of the Manufactures of Ivory Ware, which has enriched the City of *Dieppe*, ſo long as that Matter continued in the Eſteem of the Public.

The Diſcoveries of the *Portugueſe*.

The *Portugueſe* being obliged by the Smallneſs of their Territory, to look out for Means to extend it, and ſeconded by the advantageous Situation of *Liſbon* and *Porto*, were thoſe who had moſt at Heart the finding out of a Paſſage to the *Indies*, other than by the *Red Sea*. During the whole XVth Century, the Kings of *Portugal* were moſt earneſtly taken up with that Project. They ſent People to viſit all the Weſtern Coaſt of *Africa*. Their Pilots found out *Madeira* in the Year 1420, or thereabouts. The Colony they ſent thither, ſet on Fire the Foreſt which covered the whole Iſland, and made it a good Eſtabliſhment, where Plenty actually reigns, together with all the Politeneſs of *Liſbon*. In the Year 1449, they peopled the Iſland *Tercera*, and the other *Azores*, which ſome *Flemings* had firſt obſerved, and which were uninhabited. Theſe firſt Succeſſes encouraged the *Portugueſe*: They ſoon after made themſelves Maſters of the *Verd Iſlands*, leſs fruitful indeed than the foregoing, but uſeful for the Salt and Goats which they found there. They diſcovered the Cape *Verd* *, which is next to them, between the Rivers *Senegal* and *Gambia*. They ſettled themſelves on the Golden Coaſt, fortified themſelves in ſeveral Places of *Congo*, from the River *Zaire*, which waſhes that Kingdom, to the River *Coanza*, which croſſes the Kingdom of *Angola*. They have ever ſince been, and ſtill are in Poſſeſſion of the whole Commerce of the two laſt Countries. Though Barterings were very advantageous on all theſe Coaſts, the great Aim of Pilots, and the Wiſhes of the Court were, to find out a Paſſage to get into the Eaſt. But they were barred by a Coaſt which had no End. They carried their Re-ſearches to 33 Degrees of Southern Latitude, to which you need only add the 40 Degrees of Northern Latitude, which is the Situation of *Liſbon* whence they ſet out, and you will have the Length of their Courſe, which thus proves to be above eighteen hundred Leagues before the Diſcovery of that Paſſage.

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* Some place this Diſcovery three Years ſooner.

They had loſt all their Hopes, when being arrived to the 34th Degree of Southern Latitude, they at laſt found, that by keeping along the tedious Coaſt of the *Cafres*, they advanced towards the Eaſt, and even could go up again towards the North, by coaſting round *Africa*. In the Year 1487, they brought to the Court of *Portugal*, the agreeable News of the Facility of trading round that great Continent, and of doubling the Cape, which terminates it towards the South. They began to have better Hopes than ever, of making the Diſcovery of the *Indies*: And the Cape, which opened them a Paſſage thereto, was on that Account called the *Cape of good Hope*.

Even before this Diſcovery, ſo much wiſhed for by King *John* II, one *Chriſtopher Columbus* *, a *Genoeſe*, a great Navigator, and the beſt Geographer of his Time, had made it his chief Buſineſs, to enter into all the Views of that Prince, as he put himſelf in his Service. He thought he might with good Reaſon give this Prince to underſtand, that there was a better Way to arrive at the *Indies*, than that which was ſought for him by the Extremity of *Africa*: That in *Ptolemy*'s Maps †, the Eaſtern Lands of *Aſia* reached to the 180th Degree of Longitude, and were not yet limited: That very likely they extended ſtill a great way into the 180 Degrees of the other Hemiſphere: That they might perhaps prove to be very near the Weſtern Coaſts of *Spain:* That without paſſing through the Hands of the *Egyptians*, as the *Venetians* did, without undergoing the Rains of the Tropics twice, and the Heats of the whole torrid Zone, as thoſe did who attempted the Paſſage round the Extremity of *Africa*, they needed only take their Courſe by the Help of the Sea-Compaſs croſs the Weſtern Ocean; and that by patiently keeping near the ſame Latitude, they, without leaving the temperate Zone, would arrive either at *China*, or ſome other Parts of *Aſia*, the Commerce of which would be the Property of his Majeſty. Such was the Project of *Columbus*, and far was it from wanting Likelihood.

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* The Project of *Columbus*.

† See the Maps.

'Tis true, the Eaſtern Coaſt of *China*, according to the Accounts of the Moderns, does not extend beyond the 140th Degree of Longitude; and *Columbus* lengthened the Coaſts of *China* according to his Wiſhes, and by Thought brought them near the Coaſts of *Spain*, in the other Hemiſphere, though theſe be indeed 220 Degrees, that is, two thirds of the Globe * diſtant therefrom. But though the Inſpection of *Ptolemy*'s Maps, on which they did then depend, ſeemed in ſomething to favour the Thoughts of *Columbus*; the King did not approve them, and would not venture his Men and Ships on bare Conjectures.

Columbus went to offer his Service and Projects to *Ferdinand* King of *Caſtile*. That Prince, after having heſitated, at laſt ventured an Advance of 17000 Ducats and three ſmall Veſſels: Add to this twenty Men, and the Proviſions of a Year; and theſe are all the Preparations which procured *Spain* the Riches of the *New World*.

The new Admiral ſet out on the third Day of *Auguſt* of the Year 1492, from *Palos*, a ſmall Port of *Andalouſia*. After many Vexations, Troubles, Seditions, and Dangers, he had the Satisfaction to ſee Land the firſt: And inſtead of touching at *China*, or any other Coaſts of *Aſia*, he landed at one of the *Lucayes Iſlands*, almoſt 4000 Leagues diſtant from the Coaſts of *Aſia*. He afterwards diſcovered the

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* See Mr. *De l' Iſle*'s Globe.

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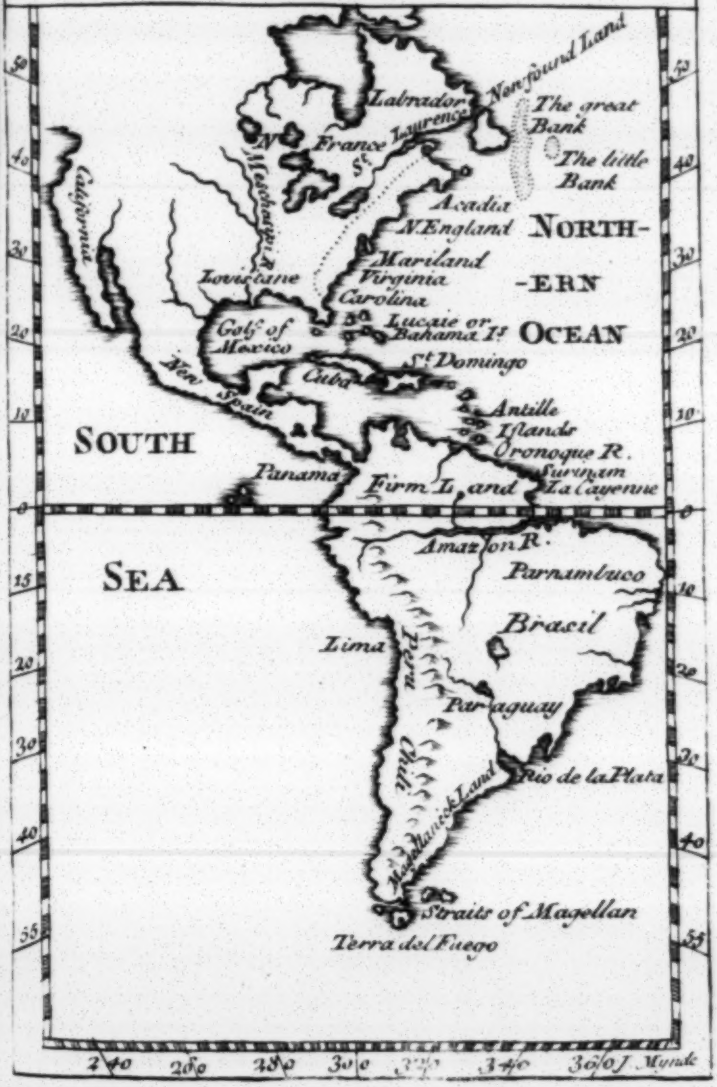
THE COLONIES OF THE EUROPEANS IN AMERICA.



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the *Greater Antilles*, viz. *Cuba*, *Hiſpaniola*, or *St. Domingo*, *Porto-Rico* and *Jamaica:* Then the *Leſſer Antilles*; and after having opened the Door of a new Continent, he brought from thence to *Spain*, Gold, Fruits, and ſeveral other Productions. He was forced by the Winds to take his Courſe through the River *Tayo*. He by the Way ſaluted the King of *Portugal*, and had the fond Pleaſure, of ſhewing him by Effects the Succeſs of a Project, which had been rejected by that Prince. Some of his Courtiers were for making away with a Man, whoſe Counſels were going to enlarge the *Spaniſh* Monarchy. But the King with Dignity replied, that the Services done the King of *Spain* were no Crimes; He, with Horror, rejected the Propoſal, and careſſed Merit, though 'twas become uſeleſs to him. *Columbus*, on the 13th of *March* 1493, went from *Liſbon* to *Palos*, where *Ferdinand* expected him. He entered the City in Triumph, with the Sounds of Bells, and the Acclamations of all the Inhabitants. Soon after, he went again to the *New World*, with ſeventeen Ships, provided with all the Supplies neceſſary for the ſettling of a powerful Colony. He did not ſucceed till he had been very often croſſed by Envy, by falſe Reports, and by the Partialities of ſome certain Genius's full of Self-conceit, and always ready to decide poſitively, what they have not the leaſt Knowledge of. The Love of Voyages and Undertakings became the univerſal Taſte: But moſt of thoſe who made themſelves known to the *New World* by theſe Voyages, being led thither by Avarice, proved Monſters of Ingratitude, Injuſtice, and Cruelty.

Americus Veſputius, a *Florentine* Merchant, went as a Paſſenger, or only as one concerned in the Undertaking, with a Fleet which ſet out in the Year 1499. He had occaſion to viſit ſome Countries, and to be a Witneſs of ſome Expeditions. But though he was without Titles, and had hardly ſeen any other than the Countries where *Columbus* had been before, he publiſhed ſeveral Accounts, wherein he attributed to himſelf the Diſcovery of *Terra firma*. His Babbling impoſed upon the People and the Court. He was doubly unjuſt towards *Columbus*, by contributing to deprive this great Man both of his Employments, and Liberty, and by robbing him by his Quackeries, of the Glory of giving his Name to the Continent by him diſcovered.

Fernando Cortés, aſſiſted and guided by the Knowledge of *Grialva,* ſubdued to the King of *Spain* the rich Country of *Mexico*, which affords Gold, Indigo, Tobacco, Cocao, and Cochineal. *Pizare* took the Opportunity of the Diviſions of the *Incas* of *Peru*, to make himſelf ſure of the Poſſeſſion of that Country, ſo abundant in Gold, and ſtill more rich by the prodigious Revenue of the Silver Mines of *Potoſi.* To both theſe Conqueſts, which procured the *Spaniards* the two fineſt Parts of *America,* they added many great Settlements in *Chili,* the Golden Mines whereof are the moſt eſteemed in the whole Univerſe, along the River of *La Plata,* the adjacent Countries to which are fruitful to *Buenos-Ayres,* and in *Terra Firma,* where they find the Cocao of *Carracos,* and the Tobacco of *La Vérine* near *Comana.*

The State of *America* has by degrees, and after many Viciſſitudes, at laſt taken a conſtant Form. The Coaſts of *Brazil* are become the Lot of the *Portugueſe,* who continually draw from thence the moſt perfect Sugar, Tobacco, Gold, Jewels, and *Brazil* Wood, which is employed, like the Fir-tree of *Japan,* in red Dyes, and in Works artificially turned.

The inner Parts of *Brazil*, the *Magellanic*, and the adjacent Countries of the large River of the *Amazons,* hitherto have excited the Deſires of none of our *European* Nations, either on account of the Barbarouſneſs of the Inhabitants, who ſtill are *Anthropophagi,* or on account of the little Value of their Productions.

. From the Iſthmus of *Panama,* which joins *North America* to *South,* the *Spaniards* are in Poſſeſſion of the Coaſt of *Terra Firma,* to the Mouths of the River *Oroonoko.* Other *European* Nations, hitherto not very curious of knowing the Heart of the Country, are contented with their Settlements on the Coaſts, from the River *Oroonoko,* to the River of the *Amazons.* The *Dutch* live at *Surinam*; the *Engliſh* at *Maroni*; the *French* at *La Cayenna,* and the adjacent Countries.

The immenſe Rivers juſt mentioned have their Supplies from the long Rains of the torrid Zone, and in the proportionable Reſervoirs, which are in the Bowels of the *Cordillieras*, the higheſt Mountains of the Univerſe, which form a Ridge of above 1500 Leagues, from the *Iſthmus* to the *Streights* of *Magellan*.

The *English* Colonies.

The fine Eſtabliſhments of the *French* and *Engliſh*, are wholly in *North America*: The *Engliſh* are there poſſeſſed of an Extent of Land above 700 Leagues in Length, on the Eaſtern Coaſt. The Iſland called *New-Foundland*, which became their Property by the Treaty of *Utrecht*. puts them within Reach of the Cod-Fiſhing on the great Bank or Shelf; but ſtill without excluding other Nations from it. *Acadia*, which the ſame Treaty has ſecured to them, has conveyed into their Hands a great Part of the Commerce of *Caſtors*, which we had with the People of *Canada*. *New-England*, *New-York*, *Penſilvania*, *Maryland*, *Virginia*, and *Carolina*, altogether, are all overſpread with *Engliſh* Families, which, together with the Natives and the Negroes which have been tranſported thither for the Culture of the Lands, form many flouriſhing and very briſk Colonies. The *Engliſh* are alſo Maſters of *Jamaica*, and ſome of the ſmaller *Antilles*. The Iſland *Barbadoes* alone, though it be not 25 Leagues in Circuit, maintains almoſt 60000 Inhabitants. I ſhould have ſaid 100000, reckoning the Negroes, were it a Cuſtom in Enumerations to reckon the Beaſts of Burden. The chief Attention of the *Engliſh* is, to draw from their Colonies Maſts for their Ships, their ſmall Timber and Wood for the Conſtruction of Buildings and Veſſels, rather than always to be obliged to go and buy them in the Wood-Yards of *Hamburgh*, or in the Foreſt of *Sweden*.

The *French* Colonies.

The *French* Colonies likewiſe are partly in the Continent, and partly in the Iſlands. Above an hundred thouſand *French* cultivate the Banks of the River *St Laurence* in *Canada*, and there live in Plenty, by means of the Corn, Vegetables, and Woods which their Lands afford; but above all, the Caſtor or Beaver, and other Furs, in which they trade with the Savages, by Exchanges of Stuffs, Goods, and all Iron Wares, which they fetch from *France*, or from the Country itſelf.

The *Louiſiana* or *Florida*, a vaſt Country watered by the River *Miſſiſſipi*, and by a Multitude of other Rivers, begins to yield the *French* more than bare Promiſes. It offers them on every Side Lodgings on an Extent of above 1800 Leagues: It preſents them every where with Fir-trees, Beech-Trees, Oaks, and Wallnut-Trees, that is, with the fineſt Woods for Veneering and for Framing. It preſents them with the delicious Fruits of hot Countries, together with the Vegetables and Corn of *Europe*, which they cannot be without. Whatever is carried to that Country, thrives there: The ſmall and large Cattle live there as well as in our own Paſtures. Horſes and other Beaſts of Burden, which multiply very eaſily, afford the Inhabitants Services leſs dangerous than that of the Negroes, and far more agreeable to Humanity. But who ſhall perſuade our rambling Families, to leave their Dunghil, and go and live honourably in that happy Country? If at leaſt the Children of thoſe who have no other Profeſſion but Beggary, were tranſported thither when young, they would ſoon forget a Country ſcarce ever known to them. In theſe new Colonies they would prove uſeful Subjects to the State, and not perpetuate among us a Party of idle Fellows, a Breed of Profligate Villains, whom we fatten out of Charity, and whom we encourage by our Bounty to be good for Nothing.

We have other Eſtabliſhments, which improve every Day. Out of the Remnants of our Colony of *Acadia*, was formed that of Cape *Breton*, over againſt the Mouth of the River *St Laurence*. The great Iſland of *St Domingo*, which we ſhare with the *Spaniards*; the Iſland of *Martinico*, and many other ſmall *Antilles*, which are now our Property, ſupply us with Tobacco, Cocao, Rocou, Vanille, preſerved Fruits, and, more uſefully, with Cotton and Sugar.

The Sea Compaſs, which has opened all thoſe rich Countries to the Nations of *Europe*, has likewiſe rendered Whale-Fiſhing eaſy to them, throughout the North. It has guided the *Engliſh* to the Bottom of the White-Sea; and by the Diſcovery of the Port of *Archangel* it imparts to the moſt Northern Nations of *Europe*, all the Productions of the South; in Return for which, it brings back to us the Marten Skins or Sables, and all the Furs of *Siberia*, Iceinglaſs, Tar, Sena, the beſt Rhubarb, and many other uſeful Drugs, which, like the latter, are ſcarcely to be found any where but in *Tartary*.

The Diſcovery of the *Indies*.

The Succeſs of the *Portugueſe*.

When the *Spaniards*, inſtead of conveying us to *China* and the *Indies*, as they deſigned, had found out *America*, which they had not the leaſt Suſpicion of; the *Portugueſe*, ſorry to ſee in other Hands what had been offered to them, reſumed their firſt Project of getting to the *Indies*, there to find an Equivalent. They in Effect arrived thither by doubling the *Cape of good Hope*, and by cauſing themſelves to be directed by ſome Pilots, whom they took in on the Coaſts of *Moſambique* and *Mombazi*. *Vaſco de Gama* had the Honour of landing at *Calicut*, on the Coaſt of *Malabar*, in the Year 1497. The *Portugueſe* under his Conduct, and afterwards under that of the great *Albuquerque*, made all the Eaſt tremble by the Novelty of their Ordnance. They made themſelves Maſters of *Ormus*, at the Entrance of the *Perſian* Gulph, and thereby Maſters of the Commerce of the Pearls at *Catif*, and of the fineſt Commodities of *Perſia*. They invaded *Diu*, *Goa*, *Cochin*, the Pearl-Fiſhing at Cape *Comorin*, and the fineſt Ports on the Coaſt of *Coromandel*. They built Forts every where; at *Bengal*, at *Sumatra*, and in all the *Molucca Iſlands*. They conquered the Iſland of *Macao* next to *China*: By which means they uſurped the Property of the whole Commerce of the *Venetians*. They even carried it on with a greater Benefit, having every thing at firſt Hand; and alone ſupplied *Europe* with the Varniſhes, *China*-Ware, and Silks of *China*, *Tonquin*, and *Cochin China*; the Cloves and Nutmegs of the *Molucca-Iſlands*, the Pepper of *Sumatra*, and of the *Peninſula* of *Indus*; the precious Stones of the old Rock of *Pegu*, *Ava*, *Golconda*, and *Viſapour*; the Cotton, Silk-Stufs, and Carpets of the *Mogul*, and the adjacent Countries; the Cinnamon or Bark of the Cinnamon-Tree of *Ceylon*; the Pearls of Cape *Comorin*, and cheifly all the Gold of *China* and *Indus*. There never was a more brillant Fortune; for which Reaſon, the Reign of *Emanuel*, the Succeſſor of King *John* II, was called the Golden Reign.

The Progreſs of the *Dutch*.

The greateſt Miſfortune that ever coul happen to *Portugal*, is, to have been re duced into a Province of *Spain*, under th Reign of King *Philip* II, in the Yea 1580, and to have remained in that State to the Yea 1640, which was the Year of the Reſtauration of the Fa mily of *Bragança* to the Throne of *Portugal*. The *Dutch* who during that Interval, did all their Endeavours t ſhake off the Yoke of the *Spaniſh* Kings, and were no acknowledged as a free Country by *Spain*, till the Peace o *Munſter* *, found no other Reſource than in the Com merce of the Eaſt, when *Spain* and *Portugal* had ſhut u their Ports to them, by which they lived before. The every where treated the *Portugueſe* as *Spaniards*: The took their Commerce and their beſt Settlements from them ſo that the *Portugueſe*, diſpoſſeſſed of all, and reduced i the *Eaſt* to almoſt no other Places than *Macao* and *Go* had loſt the chief Supports of their State, had it not bee for the Commerce of *Africa*, and the Conqueſt of *Brazi* which comforts, and perhaps fully makes them amend for their Loſs.

Though the *Dutch* have confined the Culture of Clove to the Iſland *Amboina*, of which they are Maſters; thoug they have the fineſt Plantations of all the other kinds o Spices; though they have had the Skill to exclude oth Nations from the Commerce of the Silver and Copper o *Japan*, of the Cinnamon and precious Stones of *Ceylon* and, without Diſpute, make the greateſt Figure in all th Eaſt; yet the *Engliſh* have by Degrees had ſome very ad vantageous Retreats at *Madras* in *Coromandel*, at *Sura* *Bombay*, aad *Amadabat* in *India*, at *Bander-Abaſſy*, a Se port where all maritime Commerce is carried on, an which they aſſiſted the *Sophy* in forming on the Ruins o the Eſtabliſhment of the *Portugueſe* at *Ormus*.

The Commerce of *France* in the *Eaſt*.

So long as the *French* were buſied abo nothing but Wars, or intriguing in Fo reign Courts, the *French* Merchants alwa ſaw their Wiſhes and Efforts towards ſha ing the Treaſures of the Eaſt fruſtrate But now that the Vanity of Conqueſts has made Roo

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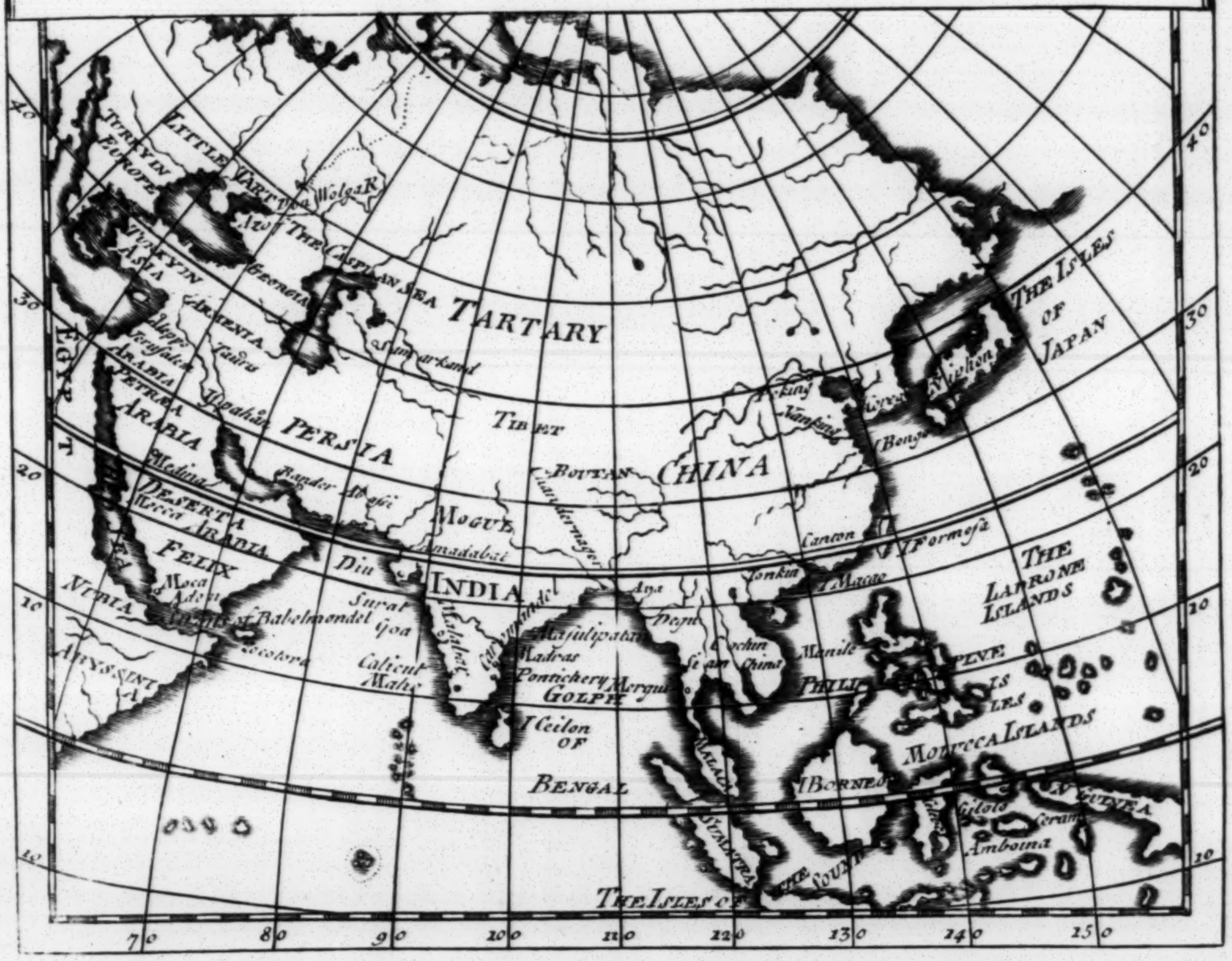
* In the Year 1648.

THE COMMERCE OF THE EUROPEANS IN ASIA.



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for the Love of ſimple Juſtice, and the maintaining of Commerce is looked upon as the Safety of the State; the *French* Company in return looks upon itſelf as the firſt Object of the Attention and Concern of the Public. We are now more agreeably taken up with all its Tranſactions, than we formerly were with the Motions of our Armies: In conſequence of which, ſome new Succeſs chears our Hearts every Year. That Company maintains its Credit by the new Eſtabliſhments it ſecures to itſelf in the Eaſt, and by the Improvement of the moſt ancient, without meddling with the Commerce of the Sea-ports in the *Levant*, or with that of *Canada*, *Miſſiſſipi*, and the Iſlands; the Profits of which are left to private Merchants. They fetch our beſt Pepper from *Mahé* in *Malabar* near *Calicut*. The City of *Pondichery*, the Property of which belongs to them in *Coromandel*, and which becomes one of the moſt flouriſhing in all the *Indies*, as well as their Settlements of *Maſulipatan*, and ſeveral other Houſes of Traffick on the ſame Coaſt, enable them in due time to fetch from all the *Indian* Kingdoms Rice, the Cardamum the Sauce for it, Steel, Cotton-wool, and Cotton ſpun incomparably finer than that made by our *European* Women, Muſlins, Calicoes painted and printed with Moulds, or ſtill more nicely illuminated by the Pencil, the Diamonds of *Viſapour* and *Golconda*, and many other Commodities which they trade in from one Part of the *Indies* to the other. By this Means, they make amends for the unavoidable Diſadvantage they lie under of making the firſt Purchaſe with ready Money; becauſe the Inhabitants of the *Peninſula* of *Indus* make little Uſe of our Wools, and *European* Commodities. The Poſt of *Chandernagor*, which the Company poſſeſſes near *Ougly*, at the Mouth of the River *Ganges*, opens them the Door into the whole Country of the *Mogul*, whence they fetch their Velvets, Brocades, fine Camlets, the beſt Indigo, the Salt-petre, the Borax, the Lac, the Muſk, and the Rhubarb, which is brought thither from *Boutan* and *Tartary*. The *French* Company, by Means of the Houſe which they hold at *Mergui* on the Weſtern Coaſt of the *Peninſula* of *Indus*, on the other Side of the *Ganges*, may alſo trade in the Rubies, and all the coloured precious Stones of *Pegu* and *Ava*, as well as in *Areque* and *Betel*, two Drugs which the *Indians* are perpetually chewing; in the Tin, Timber, Tortoiſe-Shells, and many other Commodities which are in Vogue at *Saiajutaia*, the Capital of the Kingdom of *Siam*, on the River *Menam*. They are no leſs attentive to the Exchange, (oftentimes very beneficial) which is made of Silver for Gold in the Kingdom of *China*. Their two Iſlands, called *Maurice* and *Bourbon*, at the Eaſt of *Madagaſcar*, are the commodious Staple of whatſoever they ſend from *Europe*, and bring back from the *Eaſt*.

In this ſummary Account of the Progreſs of the Commerce, which now takes in almoſt the whole inhabited World; you ſee the ineſtimable Advantages which the Knowledge of the Load-Stone procured us.

The Progreſs of Phyſics.

But if the Science of Phyſics has been of this Service to Commerce, Commerce in return has totally changed the Face of Phyſics and of all Sciences. By bringing into each Country the Productions of all the reſt, it has gradually turned all Minds to the beneficial Side. From Metaphyſics, which filled the World with unprofitable Diſputes, it brings them back to the Examination of what may be ſeen and done. While the Philoſophers of the Schools were ſpending their Lungs in public about trifling Queſtions, or privately racking their Brains, in dividing their own Ideas into Sections and Paragraphs, without ever minding whether theſe Ideas were agreeable to Nature and the World, which they carefully avoided ever looking into, there ſprung up a new kind of learned and true Philoſophers, whoſe Knowledge was grounded on Experience, and relative to our Wants. You perhaps expect here to have the Hiſtory of the Principles of *Des Cartes*, or of the Theodicy of *Leibnitz*: But not a Whit. Theſe ſhall find their Place in the Hiſtory of ſyſtematical Phyſicks. The firſt Naturaliſts which have been inſtructed by Commerce, and whoſe Learning was ſo uſeful to us, are our Navigators and Druggiſts. Let us now ſee, what we are beholden to them for.

Navigators, whoſe Numbers increaſed every Day, of Neceſſity became Mathematicians and Aſtronomers, and by Conſequence Aſtronomers and Mathematicians every where ſprung, who chiefly wrought for the Aſſiſtance of

Navigation. About the End of the XVth Century, *Purbach*, a Profeſſor of Philoſophy at *Vienna* in *Auſtria*, having by the Advice of Cardinal *Beſſarion*, learned the *Greek* Tongue, made himſelf capable of tranſlating from the original Text, the great Conſtruction of *Claudius Ptolemy*. His Diſciple *George Muller*, ſurnamed *Royaumont*, compoſed *Ephemerides*. *Stoefler*, another *German*, gave very good Directions for conſtructing the *Aſtrolabe*. In *France*, about the Beginning of the XVIth Century, *Oronce Finé*, the Royal Reader, encouraged by the Gratifications of *Francis* the Firſt, the Reſtorer of Letters, and aſſiſted, by the Accounts which then began to be ſent from the *Indies* and the new World, made Geographical Maps; conſtructed more particular Globes; invented new Inſtruments to carry on the Work both of Sailors and Perſons who made Obſervations, and inſtructed a Multitude of Mathematicians. He applied Aſtronomy to Clock-making, and was the firſt who attempted to produce an Aſtronomical Pendulum *, in which every thing moved according to the Notions of *Ptolemy*.

It muſt be confeſſed, that the Geographical Maps, which we have of thoſe Times, are extremely defective. They ſometimes have *America* divided into two Parts towards the Middle; though the Northern *America* be joined with the Southern by the *Iſthmus* of *Panama*. They moſt commonly ſhew a Paſſage towards the North into the South-Sea, though the *Engliſh*, *Danes*, and *French* Pilots, have always ſought for it in vain: Juſt as the *Dutch* have to no Purpoſe looked for a Paſſage round the North of *Tartary*, to get into the Eaſt. So that the Inutility of all theſe Attempts, makes us preſume, or even affirm, that *Tartary* is joined to *America*, and that we muſt no longer think of going to the *Indies* or *China*, by the North of *Tartary* or the the North of *America*. We very often find in theſe ancient Maps, the *Southern America* lengthened out to the Meridian Pole; though *Magellan* and *Le Maire* have, by turning round it through the *Magellanic Streights*, and behind the *Iſland of Fer*, informed us, that *America* is ſeparated from *Terra Auſtralis*. Notwithſtanding theſe

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* It is kept in the Monaſtery of *St Geneviéve*.

Defects, and many others, if all the old Treatiſes of the Philoſophy of the Schools (the Heap of which would indeed be very large) were put on one Side, and the Maps of *Peter Apian* or of *Oronce Finé*, unfiniſhed as they were, on the other; I ſhould ſet no other Difference on their Value, than that which is between rough Diamonds, which in Time will be faſhioned, and Dreams which deſerve nothing but Oblivion.

When the ſeveral Parts of the Mathematics had once enchanted all Minds, by the Exactneſs of their Demonſtrations, and the vaſt Uſefulneſs of their Productions; the Philoſophy of the Schools was looked upon as a temporary Exerciſe, which might, they ſaid, be made uſe of to ſharpen the Wits of Youth: But they reliſhed and conſequently applied themſelves to uſeful Phyſics, which filled Mankind, not indeed with empty Words, but with real Things. The Study of Geography and the Globes, that of the Winds, the Tides, and the Moon, of the Heavens, and all their Motions, of Compaſſes, and all their Uſes, of Arithmetic and Mechanics, came every where into Favour, and met with ſure Rewards in the nice Taſte of Princes, and the Gratitude of the Nations which were enriched by that ſort of Phyſics.

Next to Travellers, who have awakened Curioſity amongſt us, and made us ſenſible of the Neceſſity of Mathematics, thoſe who have promoted the Advancement of Experimental Learning moſt, are our Druggiſts; who, by ſetting in order the foreign Productions, have as it were, gathered before our Eyes the Particularities of the whole inhabited World. Theſe rich Collections of the Works of Nature opened new Treaſures to Pharmacy, to Dyers, Goldſmiths, Painters, Chymiſts, and to Arts and Sciences in general. All found therein new Trials to make, new Hints of Truth, and ſure and ſolid Informations.

Natural Hiſtory was then undeceived, with regard to the Origin and Virtues falſly attributed to ſeveral Productions of Nature, and daily diſcovered the Uſefulneſs of ten thouſand others which ſhe knew not: Nay, Anatomy itſelf, which ſeems not to ſtand in any need of the Aſſiſtance of Foreigners, found in the Diſſection of the Animals unknown to *Europe*, the Confirmation of what was as yet only ſuſpected, and the aſcertaining of what had hitherto eſcaped our Reſearches. They at laſt grew weary of unfruitful Diſputes, and of Notions daily contradicted by the Inſpection of Nature. By degrees we are come to that wiſe Method of inveſtigating of Truth, not indeed by Arguments, or the Authority of any Philoſopher, but by Experience, and by the Conveyance of our Hands and Eyes. The Study of the Productions of Nature, or of the Uſes to which they may be applied, (a Work formerly looked upon as but Loſs of Time, or an Employment fit only for Tradeſmen) is now thought the only valuable Philoſophy. A Prince or a Lord, among us as well as among our Neighbours, would be pitied, ſhould he talk of metaphyſical Degrees: But he thinks it an Honour, to have a Virtuoſo's Cabinet; and the more he is acquainted with every minute Individual of it, the more he ſhews himſelf informed, of the true Concerns and Works of that Society, to the governing of which he was appointed by Providence.

The Care which good Maſters now a-days take to clear Philoſophy from frivolous Queſtions, to treat therein at large Geometry and Mechanics, and to make the whole to refer to Experience and the Neceſſaries of Life, is a juſt Motive to applaud the Cuſtom of truſting them for two Years together, with ſuch of our Youth as are deſigned to fill the Poſts in Church and State. But their Labour might be rendered incomparably more uſeful, if, in order to improve the Maſters themſelves, their School (at leaſt in large Cities) had in it a Virtuoſo's Collection, a Garden of uſeful Plants, and a regular Courſe of phyſical Experiments.

One might copy in little, the Order of the magnificent Cabinet of Rarities, both artificial and natural, of Mr. *Bonier de la Moſſon**. We find the Model of a ſmall Garden of five or ſix hundred uſeful Plants, in Mr. *De la Serre*'s † Garden, where the Tickets which are placed near each of theſe Plants, are in lieu of Maſters and Informations. A Model of an excellent Courſe of Experiments may be taken from that of the Abbey

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* *Rue St. Dominique.*

† *Fauxbourg St. Jaques, proche de l'égliſe de St. Jaques du Haut-pas.*

Nollet *, where every Body may, without any earneſt Application of Mind, and in leſs than twenty Conferences, be informed of the moſt important Points of Natural Philoſophy.

The Prince and the Magiſtrate, the Preacher and the Merchant, and all ſuch as either manage Conſciences or the Intereſts of Nations, might, in theſe agreeable Demonſtrations, learn how to talk, and knowingly deliver their Opinion of whatever is uſeful. They might find in a Cabinet of Natural Hiſtory, of Mechanics and Experimental Phyſics, the Patterns of whatever Men can collect, exchange, manufacture, or work; as alſo of all the Falſifications which may be made therein. In ſhort, they might find there the Matter of Commerce and Induſtry. An Eſtabliſhment like this, would have the uncommon Advantage of fitting all Conditions and Genius's, of attracting all Men, and of tiring none, of forming and refining our Taſte, of maintaining Curioſity and Correſpondences, every where, of keeping many Eyes opened on the Particularities of every Country, of adorning the Mind with a Knowledge every where manly and becoming, of even affording the Topics of the moſt entertaining Converſations, and (what is indeed an ineſtimable Point) of affording every Body an infallible Means of buſying himſelf uſefully. A Philoſophy like this would, in ſome Senſe, be *the Art of living happy*.

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* *Quai-Conti.*

THE

TELESCOPE.

DIALOGUE VI.

THE particular Account of the Experiments of modern Philoſophy has no Bounds; and yet we cannot avoid preſcribing Limits to ourſelves. I then ſhall think myſelf to have gone through the whole Hiſtory, and yet have made it ſhort, if I confine myſelf to ſuch Experiments as are moſt fruitful in great Effects, and chiefly to the three Inventions of the XVIIth Century, that caſt the greateſt Light on all the Parts of natural Knowledge. You ſee, Sir, that I mean here the Teleſcope, the Air-Pump, and the Microſcope. Theſe three Inſtruments are in Aſtronomy and in univerſal Phyſics, what the Furnace is in Metallurgy, the Lever in Mechanics, and the Compaſſes in Geometry. They every Day make us diſcover, either in the Order of the Heavens, or in the Texture of Bodies, or the Relations the ſeveral Parts of Nature have with our Wants, a croud of Truths which were not known, or evident Proofs of what we had but an uncertain Glimpſe of. Theſe three Inſtruments are become Guides to all Obſervers: And acquainting one's ſelf with the Diſcoveries, for which we are beholden to the Teleſcope, the Air-Pump, and the Microſcope, is Learning the nobleſt Parts of both practical and ſpeculative Phyſics.

The Invention of the Teleſcope.

A ſort of Chance gave Birth to the Invention of the Spying-glaſs or Teleſcope. The Children of a certain Spectacle-maker of *Middleburgh*, in the Iſland of *Zealand*, playing in their Father's Shop, made him obſerve, they ſay, that when they held between their Fingers two Spectacle-glaſſes, and put them one before another, at ſome Diſtance, they ſaw the Weather-cock of their Church much bigger than ordinary, and as if it were very near them, but in an inverted Situation. The Father, amazed at this Singularity bethought himſelf of adjuſting two Glaſſes on a Board, ſupporting them in two Braſs Circles, which might be removed or ſet cloſer *ad libitum*: By this Means they could ſee better and farther. Many Virtuoſo's flocked to the Spectacle-maker: But this Invention remained a while unfiniſhed, and of no Uſe. Some other Workmen of the ſame City, one called *Zachary Janſſen*, and the other *James Metius*, in Emulation of each other, made Uſe of that Diſcovery, and by the new Form they gave it, made all the Honour of it their own. One of them, conſidering the Effects of Light, placed the Glaſſes in a Tube blackened within. By this Means he diverted and abſorbed an infinite Number of Rays, which by reflecting from all ſorts of Objects, or from the Sides of the Pipe, and by not reaching the Point of Reunion, but falling on one Side, confuſed or dimmed the principal Image. The other, ſtill more cautious, placed the ſame Glaſſes within Pipes jointed, and ſliding one in another, both to vary the Proſpects by lengthening the Inſtrument at one's Will, according to the Wants of the Obſerver, and to render the Machine portable and commodious, by the Diminution of its Length, whenever it ſhould be either removed from one Place to another, or laid by, and no longer made uſe of. There are ſome Conteſts among the Learned, about the Share which the two before named Artificers had in the Invention of the Teleſcope. I ſhall ſpare you Quotations and tireſome Diſputes, by barely affirming, that ſeveral Men, by the Variety of their Trials contributed to the Perfection of that Inſtrument; and that it is to the *Dutch* the Public is indebted for ſo noble a Preſent. When it firſt appeared, it had no other Name but that of *Lunette d' Hollande*.

It was ſoon noiſed abroad; and *Galileo*, Aſtronomer to the Grand Duke of *Tuſcany*, having heard of it; they ſay, that without having had as yet any Model before his Eyes, and on the bare Idea which the only Recital gave him of them, he framed ſeveral large Glaſſes, and adapted them to ſome long Organ-Pipes, with which he perceived ſome Spots about the Sun. He ſaw that Star moving on its Axis in near 26 Days: He diſcovered the four Moons of *Jupiter*, and called them the Stars of *Medicis*. He had a Glympſe of two Ears or Handles on both Sides of *Saturn*, which afterwards proved to be a large luminous Ring, wherewith this Planet is encompaſſed. In ſhort, he ſaw a new Heaven, and a Sun quite different from that hitherto ſeen. He * ſoon gave the Public *ſome News of thoſe Starry Regions*, which his Glaſs put within his Reach. Here I uſe the very Title of the agreeable Account he publiſhed of his Diſcoveries.

This was ſoon heard of every where. No body is ignorant, that the Senators of *Venice*, who were moſt eminent both for their Learning and their Love of the publick Good, invited *Galileo* to come, and in their Preſence make a Trial of his new Inſtruments. He complied with their Deſires, and in a fine Night neither cool nor cloudy, he ſhewed them with his Teleſcope, the Novelties which Fame began to make public, and which the Learned refuſed to admit of, becauſe they overthrew all their Notions. That Night was fatal to the Syſtem of the Schools; and the perfect Conformity which *Galileo* cauſed the *Venetian* Nobility to remark, between the new Obſervations and the Syſtem of *Copernicus*, began to give Credit to that Syſtem. Never Conference was ſo illuſtrious or of greater Concern. But nothing hinders us from aſſiſting thereat, and hearing *Galileo* himſelf ſpeak. Let us in Thought be tranſported to the Tower of *St. Mark*. The Maſter we are going to hear, the Audience, and the Newneſs of the Invention, all, in ſhort, concur to make us reliſh this Aſtronomical Lecture.

The Night appointed for the Rendezvous is come: the Stars begin to ſparkle on all Sides: their Number and Splendor increaſe on the Diminution of the Crepuſcle: the

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* *Nuncius Sidereus.*

Tubes are mounted and pointed: The Lords come upon the Tower: moſt of them already have ſatisfied, one after another, their firſt Curioſity, by directing the Glaſſes towards ſeveral Points of the Heaven. But the Planet *Venus* ſeen after Sun-ſet in the greateſt Diſtance it can be in with regard to that Star, being the fineſt of the nightly Flambeaux which then ſtrike their Eyes, all turn their Attention thither; and their Surprize is extreme, of finding in the Glaſs the Figure of *Venus* obſcured one Half, and horned from Side to Side; inſtead of appearing round in the Glaſs as it does in the Eye. How! Is then *Venus* to be eclipſed? But how can that be, when the Earth is not between her and the Sun? Does ſuch a thing ever happen? Is there any other Body beſides the Earth, that can caſt its Shadow on that Planet? Is *Venus* ever eclipſed? Or has *Venus* its various Phaſes as well as the Moon? Has ſhe alſo her Creſcent and her Full? To all theſe Queſtions, and a great many others inceſſantly multiplied, here is *Galileo*'s Anſwer.

Gentlemen,

It is from the Obſervation of this Phænomenon, that the Deciſion of the great Queſtion which divides Aſtronomers does now depend. In order to enable you to judge of it, I am firſt to lay before you what they have thought about the Oeconomy of the Heavens. We ſhall afterwards come to the Uſe that may be made either againſt or in Favour of their Sentiments, of the Phaſes which we juſt now obſerved, and which were not known before in the Planet *Venus*. I cannot entertain the Company with a nobler and more agreeable Topic, till the Riſing of the other Planets; in which I am to obſerve to you Singularities no leſs unheard of than is the Creſcent of *Venus*.

The Syſtem of *Ptolemy*.

Eudoxus, *Ariſtotle*, *Hipparchus*, and all the *Greeks*, who began to ſearch into the Order of the Heavens; *Ptolemy*, who in the II^d^ Century improved Aſtronomy; after him the *Arabians*; next to theſe *Alphonſo* King of *Caſtile*; *Sacro boſco* Profeſſor at *Paris*; *Purbach* in *Auſtria*, in the XV^th^ Century, and his Diſciple *Royaumont* in the XVI^th^; in ſhort, almoſt all the Aſtronomers have made the Earth the unmoveable Centre of the Univerſe. They ſuppoſe that the other Planets revolve round the Earth, in ſo many different Heavens, nearly concentric, and raiſed one above another, *viz*. Firſt, the *Moon*; then *Mercury*, and then, in Order, *Venus*, the *Sun*, *Mars*, *Jupiter*, *Saturn*, and at laſt the fixed Stars. It was not an eaſy Matter for them to conciliate the daily Motion which carries the Stars round the Poles of the World from Eaſt to Weſt, with another peculiar and very ſlow Motion, which carries them away round the Poles of the Ecliptic, and from Weſt to Eaſt, in the Time of 25000 Years; and at the ſame time with a third Motion, which hurries them away in a Year, and from Eaſt to Weſt, round the Poles of the Ecliptic. They were no leſs at a Loſs, how to reconcile the annual, and the daily Motion of the Sun in quite contrary Ways. A new Difficulty joined to theſe about the particular Courſe of each individual Planet. They heaped up one Mobile upon another, one of which went one Way and the other another. After the firſt Mobile's, they placed ſome very large Heavens of ſolid cryſtal, which by rolling one over another, and by a mutual and violent claſhing, did communicate to each other the univerſal Motion received from the *primum Mobile*; while they by a contrary Motion reſiſted this general Impreſſion, and by degrees carried away each after its own Manner, the Planet for the Service of which it was deſigned. Theſe Heavens were ſolid; otherwiſe the upper ones could have had no Influence on the inferior to make them daily move; and they were of the fineſt Cryſtal, becauſe the Light of the Stars could not otherwiſe have penetrated the Thickneſs of theſe Arches applied one over another, nor have reached our Eyes. Many Aſtronomers were ſo moderate, as to be contented with ſeven or eight different Spheres; while others wrapt no leſs than ſeventy of them one in another. They no ſooner diſcovered ſome new Motion or Effect as yet unknown, but they immediately patched up a new Sphere. But among the reſt, nothing is more arbitrary than their Way of explaining, each after his own Method, the Singularities of the Courſe of the Planets. It is obſerved of moſt of them, that in a certain Time they advanced directly according to the Order of the Signs, that is, from Weſt to Eaſt: that they afterwards are for a while ſtill in the ſame Point of the

Heaven, and finally, that they ſeem retrograde, and to repaſs from Eaſt to Weſt, through many of the Points which they had before run over. To account for this, they all of them make the Planet roll from Weſt to Eaſt on the Border of a little Sphere, which they call *Epicycle*, while the Centre of that Sphere rolls the ſame Way on the Arch of its Deferent, that is, of the great Heaven which is peculiar to it. Whence it happens, according to them, that when the Planet aſcends the Top of its Epicycle, we ſee it go directly, and according to the Motion peculiar to the Heaven thereof. When afterwards it deſcends into the Quadrature, or under Side of the Epicycle, it ſeems ſtationary: Becauſe as much as its Heaven carries it away, according to the Succeſſion of the Signs, ſo much it deviates therefrom, by advancing in the under Part of its Epicycle contrary to the Succeſſion of the Signs. Then, they ſay, it muſt appear retrograde, when advancing in the inferior Part of its Epicycle from Eaſt to Weſt, and quicker than its Heaven advances from Weſt to Eaſt, it is ſeen going back, till it again appears motionleſs and ſtationary; when again aſcending the Side of its Epicycle, it advances one Way no more than its Heaven advances the contrary Way. It is no eaſy Taſk to tell you, how their Epicycles could move through theſe thick Cruſts of Cryſtal: They however found Means to extricate themſelves; and as they always had their Recourſe to Geometrical Lines, which never found any Obſtacle to their Paſſage on Paper; the whole paſſed for true Phyſics. They foretold Eclipſes, and the Returns of the ſeveral Aſpects: who, after that, could have doubted of their having the Key of the Structure of the Heavens? It is true, in order to make all thoſe Pieces move with as little Inconſiſtency as poſſible, eſpecially when they were to give their Spheres different Centres, they were forced to delineate ſome certain Furrows, or to notch on the Arches ſome Grooves, in which they jointed, and made the Tenons and Mortiſes of their Epicycles to ſlide. All this celeſtial Joiner's Work, to which others ſtill added ſeveral Pieces, fit therein to produce Balancings, or perpetual Goings backward and forward, did ſo much diſpleaſe the King of *Caſtile*, (who for want of ſomething better took the whole for good Truth) that he one Day ſaid, in the Perplexity which this Multiplicity of Orbs and Orbits gave him, that if GOD had called him into his Council, the Machine of the World would have been much leſs complex. This ſo diſreſpectful Jeſt is neither for the Honour of the Royal Aſtronomer, nor that of the Hypotheſis which gave Birth to his Majeſty's Impatience.

Aſtronomers, notwithſtanding the Liberty they took to multiply Machines according to their Wants, yet never contrived any thing that could account for the Appearances of the Motions of *Mercury* and *Venus*. The brillant Planet yonder, according to Aſtronomers, turns round the Earth as round its Centre: But according to Truth it turns round the Sun. No Aſtronomer ever ſaw the Earth between *Venus* and the *Sun*; and I can give you Proofs of my having often ſeen *Venus* beyond the *Sun*; which overthrows their Hypotheſis, and gives me an Occaſion of propoſing another more agreeable to the Experiments which the Teleſcope procures us. Were it true, that *Venus* turns round the Earth, it ſhould firſt be (as really it is) ſeen to paſs between the *Sun* and the *Earth*, that is, in Conjunction. The *Earth* ſhould alſo be ſometimes ſeen between the *Sun* and *Venus*, which would then be in Oppoſition, or 180 Degrees from the Sun; which never happens, ſince *Venus* is never ſeen more than 48 Degrees diſtant from the Sun. She then begins to draw near him again, and at laſt is loſt in his Rays. But though they ſhould, by their Epicycles and Machines, be able to account for the Appearance, according to which *Venus* never goes more than 48 Degrees from the Sun, as we now ſee it; there is ſtill an Obſervation, which muſt make us for ever diſlike the Order which *Ptolemy* thought he perceived in the Heavens.

The Planet *Venus*, which you juſt ſaw in the Teleſcope under the Form of a Creſcent, or rather as the Moon when near a Quarter old, is ſeen thus horned, merely becauſe it ſhews us a Part of its enlightned Half: It begins to draw near its Conjunction. In a few Weeks you will ſee that Creſcent grow leſs, and diſappear at laſt, when the Planet coming down between the Sun and the Earth, ſhall turn its whole dark Half towards the Earth. By degrees ſhe will diſengage herſelf from the Rays of the Sun; and being more weſterly than he, we ſhall no longer ſee her at Night, but in the Morning. She will be ſeen ſooner than the Sun; ſince the Sun being then more towards the Eaſt, will not appear above the Horizon till after her. But the more you ſhall then obſerve her Progreſs in the Morning, the larger and rounder you will ſee her every Day. The Teleſcope will make you ſee her almoſt wholly, or like the Moon near its Full: Which can proceed from no other Cauſe, but her ſhewing us at that Time almoſt her whole enlightened Half. The fuller ſhe becomes, the more ſhe is then ſeen to approach the Sun. You are ſenſible, that were ſhe then between the Sun and us, ſhe could not be ſeen at all; ſince her whole enlightened Half would then be turned towards the Sun. If then ſhe is ſeen almoſt entire, and drawing near the Sun, it is becauſe ſhe is beyond the Sun; in which caſe we muſt needs ſee her on the enlightened Side: She then turns round the Sun, not round the Earth; and if ſo, we muſt of courſe find the Proof of it in the Decreaſe of her Brightneſs, which muſt be proportioned to her Diſtance. Now, that ſhe is, with regard to us, as much diſengaged from the Rays of the Sun as ſhe poſſibly can be, and drawing near us, her Splendor muſt be very great. Of this you are now convinced, by the bare Teſtimony of your Eyes. On the contrary, when three Months hence ſhe ſhall be near her Full again, though ſeen in Front, ſhe muſt be much leſs brillant, becauſe we then ſhall ſee her only in the Neighbourhood of the Sun, and with regard to the Earth, more remote by the whole Diameter of her own Orbit. Of this I was alſo informed by the Teleſcope; and daily Experience may convince you of the ſame. Therefore *Mercury* and *Venus* (for it is with the one as with the other) do not turn round the Earth. Theſe two Planets, and very likely all the reſt, have the Sun for their Centre. *Ptolemy*'s Hypotheſis is then demoliſhed: and without coming to a Confutation of whatever is therein advanced, it is ſelf-evident, that Aſtronomical Obſervations claſh with it, and therefore it muſt be for ever rejected.

It is not enough for me, to have demonſtrated the Falſhood of that Syſtem: I muſt yet replace it by another Hypotheſis leſs compounded, and more agreeable to Appearances. But I beg of you, Gentlemen, to remember, that the new Order I now offer you, though more ſatiſfactory in all Reſpects, yet is ſtill but a bare Suppoſition. The Heaven may be very different from what I take it to be. I give you my Thoughts only as ſuch, and would willingly, if poſſible, be at Variance with nobody.

The Ground of that Hypotheſis is not mine. I am ſatisfied, Gentlemen, with the Pleaſure (indeed not inconſiderable) of communicating to you the Proofs which make it acceptable, by ſhewing you in the Heaven with this new Inſtrument, what the Eye, without that Help, could not diſtinguiſh there before, and what would have given to the Author of that Hypotheſis much greater Confidence.

It conſiſts in ſaying, that the Heaven and the Stars, with regard to us, are perfectly at Reſt, and that the Motions by us aſcribed to them, proceed only from the Earth, which moves on its Axis, and is with the other Planets carried away round the Sun as their common Centre. This Idea is very far from being new, but it met with too great a Reſiſtance from the univerſal Prejudice, to be able to gain any Credit. The *Pythagoreans*, above 500 Years before CHRIST, taught it in a very myſterious manner, as they did all their other Opinions. Afterwards *Philolaus*, *Ariſtarchus*, and above all, *Cleanthes* of *Samos*, ſcandalized a Multitude of People, by openly teaching, " That the Heaven was at Reſt, and that it " was the Earth, which was carried round the Sun, ac" cording to the Line of the Ecliptic, daily turning on " its own Axis *. " This Opinion was almoſt forgot till the laſt Century, when Cardinal *Cuſa* revived it. But neither he, or any of thoſe who maintained it before him, had obſerved enough to have a Right to overthrow the old Hypotheſis, which had been of ſo long ſtanding, and was thought to be founded on the Teſtimony of the Eyes.

At laſt *Copernicus*, born in the Year 1472, at *Thorn* a City of *Poland*, and a Canon of the Church of *Warmie*, ruminated on this Opinion again, cleared it perfectly, and by aſſiduous Obſervations found it wholly agreeable to the State of the Heavens; and having given his Books *of the Revolutions*, after thirty Years Labour, he ſurpriſed all the underſtanding and attentive Part of Mankind, by making them perceive a moſt wonderful Exactneſs and Simplicity, in an Opinion hitherto rejected as abſurd. The Sum and Subſtance which I ſhall here give you of it, will, I hope, neither be long nor needleſs.

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* Μένειν τὸν οὐρανὸν ὑποτιθέμενος, ἐξελίττεσθαι δὲ κατὰ λοξοῦ κύκλου τὴν γῆν, ἅμα καὶ περὶ τὸν αὐτῆς ἄξονα δινουμένην. Plutarch. de facie in orbe lunæ.

The Syſtem of *Copernicus*.

It is a conſtant Rule of Nature, that we ſee thoſe Objects turn or move, whoſe Images change their Places in our Eyes, or paſs from one Point of the Eye to the other, without moving the Eye or the Head. It is another Rule of Nature perfectly agreeable to the firſt, that Objects appear to us fixed, when their Images remain painted in our Eyes on the ſame Points of the *Retina*, without varying. Thence it happens, that ſitting in a Boat, all Parts of which are always in the ſame Situation, both with regard to themſelves, and with regard to us, and the Image of which conſequently does not change its Place in our Eye, we then ſee that Boat as unmoved, though it be continually in Motion. On the contrary, the Images of the Tower of *St. Mark*, of the Steeples of *Venice*, and of the Trees that ſurround your Terraſſes, change their Places in our Eyes, and paſs from one Point to another, according as the *Gondola* brings us near thoſe Objects, makes us paſs by, or carries us from them. By a neceſſary Conſequence of this Motion of the Images, it always happens, that we perceive all the Objects which reſpectively correſpond to them, as though in Motion. We ſee the Town, the Steeples and the Trees on the Water-ſide coming towards and paſſing before, or afterwards going from us; while it is ourſelves who leave the Port.

Provehimur portu; terræque urbeſque recedunt.

Let us now apply this Obſervation to the Syſtem of Nature. If inſtead of making the Sun, the Stars, and the immenſe Number of the celeſtial Bodies, to turn round and be for the Service of the Earth, which is but a Point in compariſon, it had been the Pleaſure of the Author of all Things, to make the Earth and other Planets turn round the Sun for ſeveral Months together, and each of them turn in a few Hours on its own Axis; we then ſhould ſee things go juſt as we now do. The Expence would be but very little, and yet the Effects be equally magnificent. The Stars and the Sun, though conſtantly fixed in one Place without ever leaving of it, would appear to us to aſcend, to go down, and then hide themſelves. The Earth, though conſtantly advancing in a great Circle round the Sun, and making every four and twenty Hours a whole Revolution on itſelf, would ſeem to us perfectly ſtill. It is plain that the Earth would appear unmoved, ſince all the Points which we ſee on the Earth being always in the ſame Order, both among themſelves and with regard to us, the Images of them painted in our Eyes would never change their Place at any Time. On the contrary, the Sun, the Planets, and the Stars, would ſeem to us perpetually coming up or going down, according as their Images ſhould come and place themſelves in the lower or higher Part of our Eye. The Planets, eſpecially, having a peculiar Courſe of their own, while our Earth has alſo its proper Motion, would ſeem to us to have the greateſt Variety of Motions, though they had indeed but one, and that very uniform. Let us begin with the clearing of this Point, the moſt difficult of all; after which, the daily and annual Motion will no longer be perplexing to us.

Nothing in the World can be more intricate than the Courſe of the Planets in *Ptolemy*'s *Hypotheſis:* Nothing, on the contrary, is more ſimple than all the Directions, Stations, and Retrogradations of the Planets, in *Copernicus*'s Syſtem. Give me Leave, Gentlemen, in order to make you ſenſible of the important Doctrine of the *Poliſh* Aſtronomer, on the apparent Irregularities of the Planets, here to chuſe three or four Objects on the Platform of this Tower, and at Pleaſure to make them move round an unmoveable Point, which I will call the Sun. The illuſtrious Lord *Sagrédo* *, quietly ſitting in the Middle of this

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* That *Venetian* Lord had a very tender Love for *Galileo,* and he is one of the Perſons whom the great Aſtronomer introduces ſpeaking in his Dialogues.

Place, will be ſo good to ſtand to us in lieu of that Star. He ſhall, if he pleaſes, have both the Function and the Name of it, ſince he conveys Joy and Light wherever he goes. Let us take the Footman *Veroneſe*, which I find here with his Flambeau, to repreſent the Planet *Venus*. I ſhall indifferently call him *Venus* or *Veroneſe*. As for me, I ſhall be the Earth, and in whatever I ſhall ſay of the Motions of our Globe, *Galileo* or the Earth ſhall be but one and the ſame Thing. Let *Veroneſe* turn in ſix or ſeven Minutes round the Lord *Sagredo* at a reaſonable Diſtance: I ſhall at a further Diſtance make the ſame Circuit in twelve Minutes: So that he will double or complete almoſt two Revolutions, while I ſhall make but one. *Veroneſe*, as he goes, ſhall always turn himſelf towards the Sun, in order to imitate with his Face the enlightened half of the Planet, and with the hinder Part of his Head that half of *Venus* which remains darkened. Here is now the Reſult of the Concourſe of our two different Courſes.

Now that *Veroneſe* is almoſt between the Sun and me, I ſee the Sun; but *Veroneſe*'s Face, which is turned towards the Sun, is wholly hidden from me. The Planet is then inviſible, as it draws near to its Conjunction. *Veroneſe* goes faſter than me: He paſſes under the Sun: He goes ſomewhat from me on the Right, and I begin to ſee his Face in Profil: This is the Creſcent of *Venus*. As he advances, and is ready to get behind the Sun, ſtill looking at him, he turns his full Face towards me: I then ſee *Venus* at full, or nearly ſo. I ſee her ſo, only becauſe ſhe turns, not indeed round me, but round the Sun. When *Veroneſe* (ſtill going before me, ſince he goes twice as faſt) ſhall have diſappeared a while, being hid behind the Sun, I ſhall ſoon ſee him appear again in full to the Left of that Star. As he ſhall come down towards me, ſtill looking on the Sun, I ſhall ſee his Side-face, till he wholly diſappears again, by placing himſelf directly between the Sun and me. In which Situation he offers to my View only the hinder Part of his Head You then have here the Diverſity of the Appearances of *Venus*, ſuch as the Teleſcope diſcovers them to you, very well deduced from the Circuit of *Venus* round the Sun; and the Neceſſity of that Circuit demonſtrated by Phaſes which ſuppoſe its Reality. For the Earth being never between *Venus* and the Sun; if the enlightened Half of that Planet may be ſeen almoſt full, that can only be when the Earth is on this Side the Sun, and when *Venus* proceeding on the other Side of that Star, is ready to paſs behind it.

In the ſecond Place, I beg of the Company to extend their Sight along the Parapet which crowns the Tower, and there to remark from the Right to Left a Series of Points; for Inſtance, the Stones which I have chalked and marked A, B, C, D, E, F, and as many more as the Company ſhall think fit. When *Veronèſe* makes half of his Courſe from Right to Left on the other Side the Sun, and I make the quarter Part of mine on this; I ſee his Flambeau ſucceſſively paſs from the Right to the Left, under the Stones A, B, C, D, E, F. But when afterwards, continuing his Circuit, he comes down, and places himſelf between the Sun and me, I ſee him paſs from the Left to the Right, over-againſt the Points F, E, D, C, B, A. And though he proceeds in an uniform Courſe, I ſee him running over the ſame Points of the Parapet, in a Way quite contrary to the foregoing.

If then I ſee in the Heaven the Planet *Venus*, or any other, paſs under the Stars, A, B, C, D, and afterwards ſee it turn back and paſs again by D, C, B, A; it is not becauſe it keeps not a regular Courſe, as that of *Veronèſe* was, but that Variety of Appearances proceeds from its turning round the Sun, and from the Earth's doing the ſame, but *Venus* faſter, and the Earth ſlower; whence follows the Diverſity of Aſpects, and an Appearance of Irregularity.

Now let us make uſe of a Figure, where I have delineated all thoſe Things at large and in a regular manner, in order to put ſomething of Exactneſs in the Order of the celeſtial Appearances, which I have as yet only ſketched out. The underſtanding of this Figure, though it be Geometrical, yet ſuppoſes no Knowledge of Geometry. Thoſe who govern Nations have little Time to draw Lines, or to work with Compaſſes. It is our Buſineſs to render Truth palpable to them, without perplexing them with enigmatic Demonſtrations. I ſhall be contented, with only diſtributing to the Company, ſuch

Figures as will plainly expreſs the Progreſſions, Stations and Retrogradations of the Planets *. They may afterwards examine them at Leiſure with the Explanation thereto annexed, and there remark on one Hand the amazing Fruitfulneſs of the *Copernican* Syſtem, which accounts for every thing with one and the ſame Principle, and on the other, its perfect Agreement with the Phænomena which *Copernicus*, for want of the Aſſiſtance of the Teleſcope, never knew.

In *Copernicus*'s Time, his Adverſaries thought themſelves to have a complete Advantage over him, by telling him, that if the Heaven was ordered as he pretended, *Venus* and *Mercury* muſt vary their Phaſes as the Moon did; that *Mars* in Oppoſition, that is, drawing near the Earth placed between him and the Sun, ſhould appear much bigger, and that that Planet ſhould, on the contrary, ſenſibly diminiſh, when it ſhould get behind the Sun, and recede from us by the whole Diameter of the terreſtrial Orbit. *Copernicus* agreed with them, that theſe Conſequences were juſtly drawn; and he attributed the Cauſe of the Inequality of the Appearances to the Structure of our Eyes, and to thoſe radiating Crowns, which hinder us from judging either of the Bigneſs, or of the exact Form of Stars.

How great would have been the Tranſports of that great Man, had he been able, like ourſelves, to perceive the Full and the Creſcent of *Venus*, of which he found the Neceſſity, without being able to convince others of the ſame! He would immediately and for ever have ruined the Syſtem of the Schools, which makes *Mars* to turn round the Earth at an uniform Diſtance; had he but ſeen that Planet, ſuch as our Teleſcopes ſhew it us, *viz.* ſometimes receding from the Earth by a prodigious Diſtance, and diminiſhing both in Shape and Splendor, as it draws near its Conjunction on the other Side the Sun; then gradually appearing fifty or ſixty times bigger, as it arrives towards its Oppoſition, and again draws very near the Earth, placed between it and the Sun.

He would have been ſtill more pleaſed, to have diſcovered the four ſmall Moons which turn round *Jupiter*; ſince they ſhew, that our Earth in all reſpects reſembles

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* See the Explanation at the End of this Volume.

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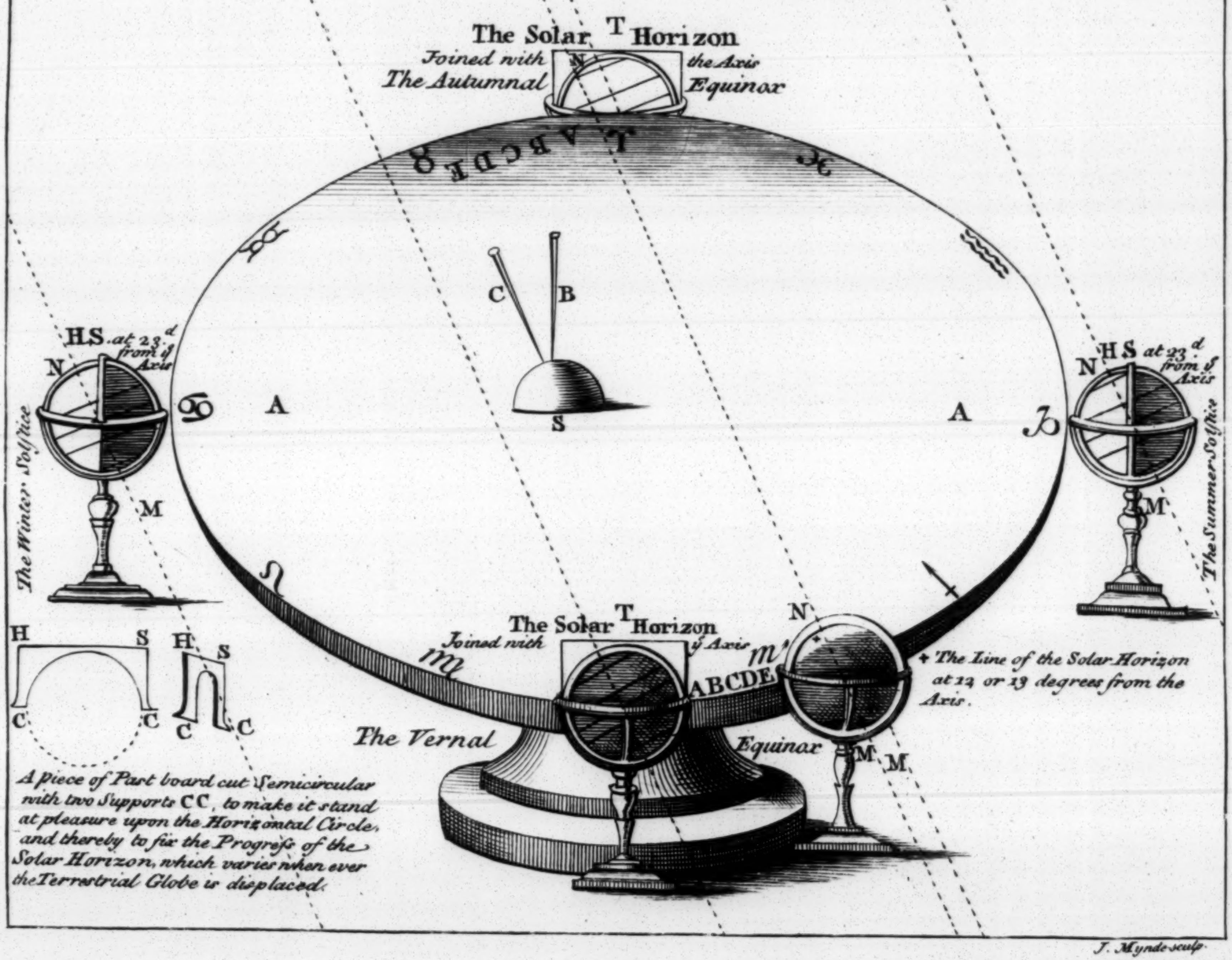
The Inequality of Seasons and Days.



A piece of Past board cut Semicircular with two Supports CC, to make it stand at pleasure upon the Horizontal Circle, and thereby to fix the Progreſs of the Solar Horizon, which varies when ever the Terrestrial Globe is displaced.

J. Mynde sculp.

any other Planet; and that as *Jupiter* has four Planets of the ſecundary Order, inſeparably bound to its Service, that is, four ſmall Moons deſigned to light it during the Night of its obſcure Half, ſo has the Earth a ſubordinate Planet, which performs the ſame Functions for her Sake. Nay, who knows but Men, with Inſtruments better ſtill than mine, will, one Day or other, diſcover, that *Saturn*, in its extreme Remoteneſs from the Sun, was ſtill better provided with the Help of nightly Flambeaux? I have already begun to obſerve there a ſort of double Handle, which reflects a very great Light thereupon *. In ſhort, whatever I daily perceive in the Heavens, becomes a new Proof of the Solidity and Exactneſs of that Syſtem, which places the Sun in the Centre of the Planetary World, and makes the terreſtrial Globe turn round him like the other five Planets.

After this Illuſtration both on the Order and Courſe of Planets, the reſt of the Hypotheſis, which accounts for the diurnal Motion of the whole Heaven, and for the Inequality of Days and Seaſons, becomes an Amuſement to divert the Mind rather than a Study.

I have cauſed here an oval Table (A) † to be placed, whoſe Plane may be looked upon as making a Part of the Plane of the Ecliptic. We may lengthen this Plane out in Imagination, and make it reach to the Middle of the twelve celeſtial Signs.

The oval Circumference of the Table repreſents well enough the Orbit or Path, which the Body of the Earth follows and deſcribes in a Year round the Sun.

That whole Circumference is divided into twelve Portions, ſubdivided each into thirty Degrees, to make them correſpond with the twelve celeſtial Signs, which I ſuppoſe to be over-againſt them among the fixed Stars. I have been content with delineating the compendious Figures of the twelve Signs on the Edges of the Table.

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* Theſe Handles which *Galileo* had ſeen near *Saturn*, were the Extremities of the luminous Ring wherewith we ſee that Planet wholly encompaſſed, when it is turned another Way.

Mr. *Caſſini* has exactly obſerved that Ring, and diſcovered four ſmall Moons by it.

Mr. *Huygens* ſaw the fifth.

† See the Figure.

At a ſmall Diſtance from the exact Middle of that Table, or terreſtrial Orbit, and not juſt in the Centre, I put half an Orange, to repreſent the Sun (S), the other Half of which may be ſuppoſed hidden under the Table.

I cauſed two Iron Pins to go through the Orange and the Table; the one (B) perpendicular to the Plane of the Ecliptic, and which I call the Axis of the Ecliptic; the other (C) inclined to the foregoing, and making therewith an Angle of 23 Degrees and a half, or, which is the ſame thing, an Angle of 66 Degrees and a half with the Plane. This I call the Axis of the World: Not that the Planetary World revolves on that Axis, but only to give us here the Idea, and the invariable Rule of the Direction we are going to aſſign to the Axis of the Earth, round which we are apt to believe that the World turns.

Let us now bring near the Edge of our Table the exact Middle of this little terreſtrial Globe T, and moving it cloſe to the Edge along the twelve Signs that divide the Oval, let us cauſe it to make a whole Turn round it. This very ſenſibly repreſents the Earth advancing in its annual Orbit round the Sun.

It is plain at firſt Sight, that if the Earth T be under the Sign of *Libra*, it will ſee the Sun under that of *Aries*. When it paſſes under *Scorpio*, the Sun will appear under *Taurus*, and ſo on.

The apparent Motions of Planets.

2. The Earth, by advancing from West to Eaſt, will by little and little ſee all the Stars move from Eaſt to Weſt, and in a Year's Time will compleat this Revolution round the Axis of the Ecliptic, becauſe it is alſo the Axis of the terreſtrial Orbit. There is no Man but has often remarked towards the Eaſt, at the Beginning of Night in Autumn, the *Hyades* forming a large V in the Sign *Taurus*, and pretty near the ſame Place the Platoon or Cluſter of the *Pleiades*. Some Months after they appear to be pretty high at the Beginning of the Night, and from one Night to another, they inſenſibly draw more and more to the Weſt. They then appear to move in the Compaſs of a Year from Eaſt to Weſt, becauſe the Earth recedes from every one of them in the contrary Direction

It is not thus with the Sun. I paſs under, and not round the Stars, whereas I abſolutely turn round the Sun. He reſembles a Flambeau in the Middle of a large Hall. As I walk round the Flambeau, my Eyes ſee it on ſome of the Points of the Wall which bound, my Sight. If there are twelve Chairs round the Hall ranged in the following Order, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. When I ſhall paſs by the Chairs 1, 2, 3, 4, 5, 6, I ſhall ſee the Flambeau before 7, 8, 9, 10, 11, 12; and when I paſs before 7, 8, 9, 10, 11, 12, I ſhall perceive the Flambeau ſucceſſively againſt 1, 2, 3, 4, 5, 6. It then makes, or appears to make oppoſite to me, the ſame Motions as I do. In like manner, when we paſs together with the Earth under the thirty Degrees of *Libra* in the following Order, A, B, C, D, *&c.* from Weſt to Eaſt, we needs muſt ſee the Sun under the Degrees of *Aries* in the ſame Order, A, B, C, D, *&c.* from Weſt to Eaſt. He muſt then appear to make his annual Courſe from Weſt to Eaſt, and daily advance forward therein, according the Succeſceſſion of the Signs.

3. But while the Stars ſeem annually to move Weſtward, and the Sun annually Eaſtward round the Axis of the Ecliptic, the Whole ſeems every four and twenty Hours to revolve from Eaſt to Weſt round the Axis of the Earth: A Diverſity which can proceed from no other Cauſe, but the two-fold Motion of the Earth revolving in one Year on its Orbit round the Axis of the Eliptic, and in twenty-four Hours on itſelf, that is, round its own Axis.

4. If the Portion of the ſix Southern Conſtellations is made a ſmall Matter larger than the other Half, and the Sun be not exactly in the Middle of the Orbit, the Earth being ſeven or eight Days longer in the Southern Signs, ſhall ſee the Sun eight Days longer in the Northern, as is agreeable to Experience.

5. When the Earth, yearly advancing in her Orbit, keeps the Axis on which it revolves every four and twenty Hours perfectly right and parallel to the Axis of the Ecliptic, without inclining to either Side, then will the Sun and Stars always keep an uniform Aſpect with regard to all Nations. Days ſhall be neither ſhorter or longer in one Seaſon than in another; and Seaſons

will always be the ſame, or rather, there will be but one Seaſon. The only Variation of the Heaven will conſiſt in the annual Progreſs of the Stars towards the Weſt, and of the Sun towards the Eaſt: But the Points of the riſing and ſetting will not change. It is ſelf-evident, that this is not the Oeconomy of the World.

The Inequality of Seaſons and Days.

In order to underſtand, and to fix at once the Inequality of Days and Seaſons, we need only to incline the Axis of the Earth twenty-three Degrees and a Half to the Axis of the Ecliptic; always keeping that Axis parallel to that of the World (C), and to obſerve well the Points of the Globe, where the Half which is enlightened by the Sun terminates. The inclining of the terreſtrial Axis, the conſtant Paralleliſm of that Axis, and the greater or leſs Remoteneſs of the Solar Horizon with regard to that Axis, are the Source of the Inequality of Days and Seaſons.

Let us, by the Aſſiſtance of a Figure, render this Solar Horizon, and all its Viciſſitudes or Changes of Place, more eaſy to be conceived. This Paſte-board H. S. which I have made into half a Circle, being perpendicularly placed on the Middle of the terreſtrial Globe, may be a very juſt Repreſentation to you of the Edges of the enlightened Half which is towards the Sun, and of the obſcure Half which is on the other Side. I ſhall call this Paſte-board the ſolar Horizon. I have faſtened the two Legs of the Semi-circle H, S, with two little Supporters in the Form of Shoulder-pieces; that we may be able to fix it, ſo as to make it ſtand at Pleaſure, on what Place ſoever of the terreſtrial Horizon we ſhall think fit. Inſtead of a whole Circle, which we ſhould have to repreſent the Half of the Earth enlightened by the Sun, I am contented with a Semi-circle, that I may make it ſlide more eaſily, and put it wherever I pleaſe. Imagination may prolong it under the Globe, and ſupply the reſt.

Let us place the Earth T under *Aries*, with the Axis N, M, parallel not to the Axis of the Ecliptic B, but to that of the World C, and the ſolar Horizon facing the Sun. In this Situation, the Axis of the Earth N, M, lies in the Plane of the ſolar Horizon, that is, that the

Arctic Pole N, may be exactly at the Border of the ſolar Horizon on one Side, and the Antarctic Pole M, at the South Part and Border of the ſame Circle, which marks the Limits of the Night and the Day. The Sun cannot enlighten any thing more by his immediate Light. All the Points of the Earth, by revolving round that Axis in four and twenty Hours, viſibly make half of their Revolutions in the enlightened Part, and the other Half in the obſcure Part. There is then that Day, *viz.* the 23^d^ of *September*, an univerſal Equinox; whence the Sign under which the Sun then ſeems to be, has borrowed its Name of *Libra*, or the *Scales*. By changing the Earth's Place, and bringing it to the firſt Degree of *Taurus*, you ſee that the enlightened Half is no longer the ſame. The Borders of it neceſſarily have ſlid, as it were, to other Points. We are obliged to place the ſolar Horizon in ſuch a manner as that it may exactly face the Sun. If you turn both the Axis and the Earth and the ſolar Horizon in ſuch a manner, that the one does not leave the other, it makes a Situation entirely like the foregoing, and you will again have an Equality of Days and Nights; ſince all the Points of the Globe will in their daily Revolution, be as much above as below the ſolar Horizon. But if the Axis of the Earth N, M, ſhall remain parallel to that of the World C, while the ſolar Horizon changes its Place; then every thing changes with it. The ſolar Horizon cuts the Axis at the Centre; ſo that one half of the Axis M is on this Side of the ſolar Horizon towards the Sun, and the other Half on the oppoſite Side. One of the two Poles is then more and more engaged in the enlightened Half, and the other Pole ſinks more and more into the obſcure Part. We now begin to ſee, that the Points or Nations which turn together with the Earth towards the Pole that looks towards the Sun, may be longer in the enlightened Half than in the other. But this will become more evident by placing the Earth under the Sign *Cancer*. She then ſees the Sun under *Capricorn*; and keeping her Axis parallel to her foregoing Situation, or to the Axis of the World C, ſhe removes her arctic Pole N from the Sun, and inclines her antarctic Pole M twenty-three Degrees and a half towards the Star. Had ſhe her Axis parallel to that of the

the Ecliptic, ſhe would ſee the Sun paſs through all the Points of the Equator: But having then her Axis on the Side M, inclined twenty-three Degrees and a half towards the Sun, ſhe ſees him twenty-three Degrees and a half above her Equator; and as ſhe on that Day, *viz.* the 22^d^ of *December*, preſents to him, in her Revolution from Weſt to Eaſt, Points always diſtant twenty-three Degrees and a half from the Equator; the Sun will from Eaſt to Weſt appear to delineate the Tropic of *Capricorn*. If thence the terreſtrial Globe T ſucceſſively advances under *Libra*; the Circle of the ſolar Horizon, in order to face the Sun, changes its Place a little, forms a ſmaller Angle with the Poles, and at laſt approaches them anew, or joins them again, when the Earth, being under *Libra*, ſees the Sun in *Aries*. That Day, which is the 21^ſt^ of *March*, the two Poles again cut the two Sides of the Horizon: Neither of the Poles is inclined towards the Sun, which by neceſſary Conſequence muſt fall upon one Point of the Equator: And as the Earth in its Revolution, brings on all the Points which are at an equal Diſtance from the Poles, the Sun, on that Day, ſeems to deſcribe the Equator. Beſides, all the Points of the Globe, by ſucceſſively going up and down, are as long above as they are below the ſolar Horizon. They then have all twelve Hours Day, and as much Night, on the 21^ſt^ of *March*.

The very next Day the ſolar Horizon changes its Place; but the Axis is not altered in the leaſt. The ſolar Horizon does then begin to recede therefrom, and to leave the Arctic Pole N, which remains elevated in the enlightened half; whereas the other Pole M begins to be immerſed in the obſcure half. The ſolar Horizon every Day recedes from the Arctic Pole, till the Earth being placed under *Capricorn*, the Limits of the ſolar Horizon are diſtant 23 Degrees and a half from the Arctic Pole N.

In this Situation, wherein all is very obvious, let us chuſe three or four Points, or three or four Countries differently ſituated, in order to know what will happen on this occaſion to them. Let us, for Inſtance, take thoſe under the Poles, thoſe who live under the Polar Circle, thoſe

hoſe under the Tropic; and laſtly, thoſe who dwell under he Equator.

1. Thoſe who are under the Pole N, or that have he celeſtial Pole for their Zenith, have the Equator for heir peculiar Horizon. Now the Equator here is twenty-hree Degrees and a half below the Sun: They then ſee im revolve round them at the Height of twenty-three Degrees and half above their Horizon. There have been lready three Months ſince theſe People came to the Verge of the enlightened Half, and they will be three other Months more before they reach the other Limit of hat Half: They have then a Day of ſix Months long. They will be afterwards ſix Months, or nearly ſo, under he ſolar Horizon; and conſequently all that Time without ſeeing the Sun. The People next the Pole, making heir daily Revolution between the Axis and the ſolar Horizon, will be ſeveral Months together without touching the ſolar Horizon; and conſequently have a Day ſeveral Months long. For this Reaſon they diſtinguiſh he Climates towards the Poles by Months, hat is, in Degrees, or by Nations, the Days of which may, among themſelves, differ by the Space of one or more Months.

The Monthly Climates.

2. What will happen to thoſe who are under the Polar Circle? Since they are twenty-three Degrees and a half diſtant from the Pole, and the Pole is as much diſtant from the ſolar Horizon; all thoſe who are under the Circle, or at that Diſtance from the Pole, ſhall on the 22d of *June* make their diurnal Revolution round the Axis, without paſſing under the ſolar Horizon. They will indeed come cloſe, or graze upon, but not touch it: They then will have one Day four and twenty Hours long; and thoſe who are ſomewhat leſs remote from the Pole, may be ſeveral Days together without deſcending under the ſolar Horizon. Theſe may then among themſelves be diſtinguiſhed by daily Climates, that is, Climates where the Increaſe of the Light ſhall come to one, two, or three, or even more Days long.

Daily Climates.

3. But all ſuch as are four and twenty Degrees, and more, remote from the Pole, even as far as the Equator,

make with the Earth a Revolution, the greateſt Part o which is in the enlightened Half, and the ſmalleſt Pa below. All theſe People have then unequal Days an Nights. None of them can have a Day twenty-fou Hours long; becauſe they all of them, ſome more, ſome leſs, cut upon the under Part of the ſolar Horizon. Fo this Reaſon, from the Equator to the polar Circle, the reckon the Increaſings of the Light from Country to Country by hourly Climates; and they aſſig a new Climate, wherever the Day is on the twenty-ſecond Day of *June*, half an Hou longer than in the preceding Climate, beginning from the Equator, where the Day is at all Times twelve Hours long.

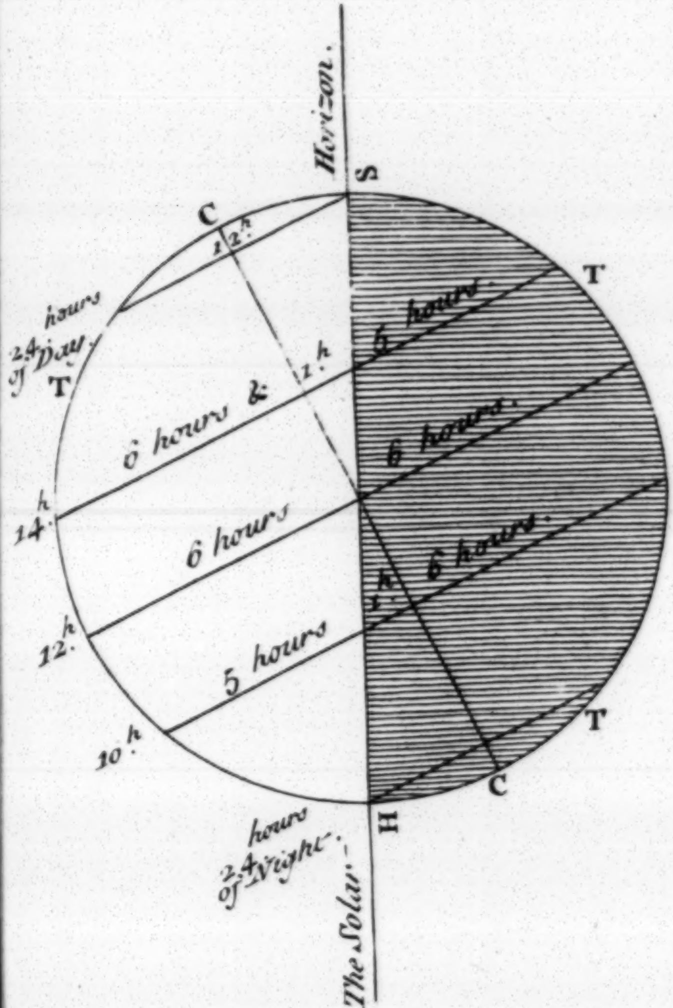
Hourly Climates.

4. Nothing can be eaſier than the Determination of the Increaſings of the Day, and of the Diminution of Nights from the Equator to the Pole. Except the two Days on which the ſolar Horizon depends on the Situation of the earthly Axis, and when the Equinox is univerſal, the ſaid Horizon every Day of the Year cuts the terreſtrial Axis through the Centre, which is the ſame with the Centre of the Equator. Each Point and Nation under the Equator, is then ever twelve Hours above, and twelve Hours under, the enlightened Half; the ſolar Horizon making with the Axis an Angle, which always increaſes from the Equinox to the Solſtice, where it is twenty-three Degrees and a half. The Day muſt needs always increaſe to that Solſtice, in the Half which looks towards the Sun, and that increaſing muſt be every Day greater and greater from the Equator to the Pole.

Let us chuſe out a Point or a Place ſituated twenty-three Degrees and a half above the Equator, that is, under the Tropic of *Cancer*; for Inſtance, *Sienna*, a City on the Confines of *Egypt*, and *Abyſſinia*, being brought to the Border of the ſolar Horizon. it will deſcribe from Weſt to Eaſt, a Circle parallel to the Equator, and on the twenty-ſecond Day of *June* will ſee the Sun paſs juſt over it in a contrary Direction. Suppoſe we have a mind to know, how long the Day will be at *Sienna*. A plain Circle T may here ſerve inſtead of a Globe. We may divide each of the Parallels that croſs it into twelve equal Portions, to repreſent twelve Hours, or one half of the daily

Plate 25. Vol. IV. Page 296.

The Measure of y^e Diurnal Arks.



Ja. Mynde Sculp.

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aily Revolution. We then have, from the Point marked ut 14, where *Sienna* is ſituated, to the Axis C, ſix Portions or Hours. Let us reckon ſix other Hours from the Axis to the other Border. But we muſt ſubſtract from heſe laſt ſix Hours, what is under the ſolar Horizon, ince it is the Night which is about five Hours. There emains an Overplus, which you ſee in the Angle beween the Axis C, and the ſolar Horizon H S, which is n Hour's Day more to be added to the other ſix. But we ſee in that Circle but one half of the Revolution: We muſt therefore double the Sums, and we ſhall have for *Sienna* fourteen Hours of Day, and ten Hours of Night. And what I have ſaid of the Northern Hemiſphere, the Company may apply to the Progreſs of the Night and Day in the Southern Hemiſphere. Thus all the Motions ſo various of the Stars and the Sun, the Inequality of Seaſons and Days, in a Word, all the Variations of the Heaven, are a plain Conſequence of the annual Paſſage of he Earth round the Sun, and of her Revolution in four and twenty Hours round her own Axis, invariably directed and pointing towards the North.

The Preceſſion of the Equinoxes.

There remains but one Phænomenon, which I have not yet accounted for. The celeſtial Signs, in a certain Number of Years, ſeem by little and little to quit the Points under which they were ſeen before, and with regard to the Point of the Equinoxes, to recede ſeveral Degrees towards the Eaſt. In order to account for this Preceſſion, it will be ſufficient to conceive, that in a very long Series of Ages, the Axis of the Earth inſenſibly changes its Place, and deſcribes a very ſmall Circle from Eaſt to Weſt. So all the Motions of the Heavens, which are ſo contrary, and would be ſo difficult to be made to agree, were they real, want no manner of Reconciliation, becauſe they are only apparent, and the Appearances have no other Origin than the Diverſity of the Motions of our Earth. Let a Waterman, in order to amuſe his People, make his *Gondola* whirl about as he paſſes before the Tower of *St. Mark*; his Paſſengers will ſee the Tower advance, then paſs before them, then go back; and they at the ſame time will every Moment ſee it turn round them. Muſt they therefore buſy themſelves about reconciling

ciling the ſeveral Motions of the Tower? Sure it did not ſtir from its Place, and all theſe Appearances have their Origin, both in the ſucceſſive Progreſſion, and in the turning of the *Gondola*.

But the Planet *Jupiter*, which now ſhews itſelf clearly, invites us to reſume our Teleſcopes, and look out for the four little Moons which attend it.

Such is the Ground and Subſtance of *Copernicus*'s Doctrine which *Galileo* laid before the *Venetian* Senators, and of the Exactneſs of which he made them ſenſible, by ſhewing them in Nature, with his new Inſtruments, the Demonſtrations of the ſame. But let us imitate his Modeſty: What he gave only as a ſatisfactory Hypotheſis, let us propoſe as a bare Syſtem, and confeſs, that it was attacked with Objections, which at firſt ſeem very much to leſſen its Value, and its perfect Conformity to Obſervations.

Objections.

The moſt puzzling Objection to *Copernicus* was drawn from the Diverſity of the Sizes and Phaſes under which the Planets ſhould be ſeen, by receding from or approaching near the Earth. *Copernicus* confeſſed, that the thing ſhould indeed be as they ſaid, and he propheſied, that one Day or other theſe Varieties would be diſcovered. *Galileo* has accompliſhed this Prophecy: Therefore the Objection becomes a Proof, and the Efforts which were made to overthrow this Hypotheſis, had no other Effect than to make it ſtill more acceptable.

The ſecond Objection which was propoſed to *Copernicus*, and afterwards to *Galileo*, is, that if the Earth deſcribes an Orbit ſeveral Millions of Leagues broad, the terreſtrial Axis, always parallel to itſelf, muſt correſpond with ſuch or ſuch a Star, when the Earth is in *Libra*, and ſix Months after, when in *Aries*, muſt correſpond with another Star, diſtant from the preceding by as many Millions of Leagues, as are contained in the Diameter of the Orbit. Nevertheleſs, we ſee the terreſtrial Axis, at one Time as well as another, conſtantly turned towards one Point of the Heaven, *viz.* two Degrees and a few Minutes diſtant from the Polar Star.

This Objection never puzzled *Copernicus*; becauſe it was eaſy to ſee that the Diſtance of the Stars from the Earth is ſo immenſe, that twenty or thirty Millions of Leagues appear not ſenſible therein, and the two Points of the Heaven towards which the terreſtrial Axis is turned at either Equinox, though they be really as diſtant from each other as the two Extremities of the terreſtrial Orbit, yet appear to us no more than a ſingle Point. Thus two Objects ſeparated from each other by a Space of thirty, forty, or fifty Foot, ſeem to us but one and the ſame Thing, at the Diſtance of one or two Leagues.

Galileo, whom this Objection did not puzzle a whit more than his Maſter, with regard to this, preſumed to propheſy, and he did it with the ſame Succeſs with which *Copernicus* had foretold the future clearing of the firſt Difficulty [*]: "I don't deſpair (ſaid the *Florentine* Aſtronomer) but one Day or other ſome particular Tokens will be obſerved in the fixed Stars, by Means of which they may be able to know, what the annual Revolution conſiſts in: So that the Stars, as well as the Planets, and the Sun itſelf perhaps, will be ſummoned to appear in Judgment, to bear witneſs concerning the Nature of that Motion in Favour of the Earth."

Meſſieurs *Caſſini*, *Hooke*, and *Flamſtead*, the greateſt Names that we can quote for Aſtronomical Obſervations, have for ſeveral Years together carefully obſerved, ſometimes one of the Stars which paſs through the Zenith, ſometimes the Polar Star. They found that both the Vertical and the Polar Star, in their greateſt Elevation, appeared indeed under the ſame Degree of their Circle, as well when the Earth was under *Cancer*, as when it was under *Capricorn*; but that they both varied their Situations by ſeveral Seconds. The Stars have among themſelves an invariable Situation. If then, in their paſſing again under the Meridian, they make with my Zenith, or with the Axis of the Earth, an Angle different from that I had in the foregoing Obſervation, it is becauſe I have changed my Place, together with the Earth, which has paſſed from one Side of its Orbit to the other. As if from the Terraſs of the Obſervatory I perceive the Steeple of *St. Denys*, through the two Slits of the Sights of an Inſtrument, and one ſhould place the Inſtrument a few Steps farther in a like Situation, or rather parallel to the foregoing. The Steeple ſhall no longer be ſeen through the Sights, and I ſhall be obliged to give them a gentle Thruſt, to bring them again exactly over-againſt the Object. The Steeple did not change its Place; and its Removal to another Proſpect or another Point of the Circle, is a Proof of the Obſerver's having changed his Place. One might be thence apt to conclude, that the Motion of the Earth makes a Part of Experimental Knowledge, and that it is Matter of Fact.

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[*] Rem quampiam olim in ſtellis fixis obſervabilem eſſe futuram, per quam cognoſci queat in quo conſiſtat annua converſio: Ita ut fixæ non minus planetis ipſoque ſole comparituræ ſint judicio, ad reddendum teſtimonium hujus motûs in gratiam terræ. *Dialog. de Syſtemate Mundi*, 1635. *Pag.* 375.

The great Objection which may be made againſt the *Copernican* Hypotheſis, is, (they will ſay) that it authorizes the Irreligion of a great many Philoſophers. Man, according to theſe, is very ridiculous to think, that it is for his Sake that the Stars ſparkle, the Sun riſes, and Nature diſplays its lofty Scenes. If the Planet *Jupiter* has four Moons, it is in order to convey Light upon it during the Night: But why ſhould Light be conveyed where there were no Inhabitants? The Planets are then ſo many Earths, and if the Stars ſhine of themſelves like the Sun, it is evidently becauſe they light ſome other Planets. We are then much in the wrong, to attribute to ourſelves the Uſe and Service of the Fires that ſparkle in the Heavens: The Hypotheſis of *Copernicus* proves, that they don't ſhine for us, but that we make uſe of them.

Whether we make uſe of them only, or whether they be made for us, is ſtill one and the ſame thing. Pray, do you think we can with any Reaſon find the leaſt Difference in that? GOD alone knows, for what particular Purpoſes he deſigned each of thoſe fiery Globes, which he in ſuch Number, and with ſuch Magnificence, has ſcattered around us. If we ſhould ſuppoſe him to have there diſtributed ſeveral Intelligences, in order to be praiſed by them; I ſee nothing in this noble Suſpicion, that can any way claſh with GOD's Majeſty, or weaken our Gratitude: And though he ſhould make them the Abodes of ſo many different Claſſes of Creatures, yet are we not a whit leſs obli-

ged to be ſenſible of the Advantage of our Condition,
to thank God for having granted us the Sight and Uſe
theſe Globes. The Inhabitants of *Paris* are not ex-
agant, when they think themſelves happy, that our
gs have flung open to them the Gardens of the *Tuille-*
and the *Luxembourg*, though thoſe who dwell in theſe
es, and even Foreigners, have the Privilege of walk-
there as well as the *Pariſians* themſelves. God's Fa-
rs are not the leſs deſigned for us, becauſe others may
ſhare them with us in common.

ut there is ſtill ſomething more: Good Senſe and
th are only to be found in the Language of the com-
n People, who ſeeing no other Being but Man, that
enjoy the Oeconomy of this World, glorify God for
ing created it in Favour of Man: Whereas Falſhood
Miſtake are palpable in the Argument of the pretend-
Philoſopher, who thinks, that the Multiplicity of
rlds ſhould be a juſt Reaſon to criticiſe on the Lan-
ge of the People. If there are Inhabitants in *Jupiter*,
have four Moons during the Night, whereas a ſingle
is ſufficient for us. Their Night is then quite diffe-
from ours. By their Remoteneſs, they muſt needs
e their Sun ſmaller than ours; or if they have an At-
ſphere otherwiſe formed than ours, they ſee it either
er, or otherwiſe coloured than we do. They then
e another Sun. Aſtronomers have obſerved from the
ection of the Spots which revolve over the Diſk of *Ju-*
, that the Axis of that Planet is perpendicular to
Ecliptic, and that the Globe makes it's Revolution
ten Hours time. They conſequently have an uniform
ſon, Days perpetually equal, a Night of five Hours,
a Day as long; while our Days are of four and twen-
Hours, and our Seaſons vary by a perpetual Alternative.
eir Year is not ours. Twelve of our Years make their
elve Months. Every thing then changes from one
ere to another. Let each of them, if you will, be re-
ed as a World by itſelf and apart: Every one of theſe
rlds has its peculiar Structure and proper Advantages.
e Inhabitants of one World do not thank God for the
der enjoyed in another. They have not the leaſt Idea
it: They thank him for what they have received.
likewiſe praiſe him for our Sun, our Moon, our Hea-

ven, our Year, our Atmoſphere, and the ſpecial Providence by which he has ſecured to us the Enjoyment of that magnificent Proſpect. We are the Centre of them; ſince we are the only People in the Univerſe for whom all theſe Cautions were taken: And as the Oeconomy of our World is not only for us, but alſo for us alone; there is neither a Preſumption or a Miſtake in the Perſuaſion Man has, that God had him in View, and vouchſafed to buſy himſelf about him: whereas the Error is palpable in the Notions of the falſe Philoſopher, who from the bare Suſpicion of the Plurality of Worlds, immediately concludes, that he is no longer the Centre of the fine Order of this, and who by multiplying them, fancies he will be able to loſe himſelf in the Croud, in order to avoid God's Goodneſs, and thus be exempted from the burdenſome Duty of Gratitude.

If it be the whole Heaven that with an inconceivable Swiftneſs turns round the Earth unmoved; this ſhall be the Work of an infinite Power, always mindful of our Wants. If it is the Earth that turns, to procure all its Inhabitants the Services of the Light, and the Sight of the celeſtial Flambeaux; if each Planet on it's part revolves round it's appointed Orbit; I here find again the ſame Power and the ſame Goodneſs, though with an Oeconomy quite different. The People may very well praiſe God for thoſe wonderful Revolutions which ſerve them ſo regularly, without making any further Enquiry into the Manner, in which the whole is performed. But if ſome Genius's more elevated and more at Leiſure, can add to the Knowledge of the Bounty, that of the Performance: When God allows them a Glimpſe of it, and begins to let them into the Secret of his Works; it is a Confidence wherewith he honours them: It is a new Motive of Praiſe; and a Virtuoſo, whom his own way of conſidering Things makes ungrateful, is the moſt horrid of Monſters.

What a raviſhing Magnificence, and at the ſame time what an amazing Simplicity in the Work of the Creator; thus to have placed his Sun in the Centre of the Planetary World, and to make a Multitude of maſſy Globes float round it, which following without Let or Incumbrance, the ſeveral Courſes preſcribed them, perpetually receive from that glorious Star, their Light, their Colour, and their Life! Each Planet enjoys their Favours of the Sun, as tho' that Star were made for it alone, or there were in our Sphere as many Suns, and even Worlds, as there are Planets therein. A Parſimony ſubſiſting with Effects ſo fruitful, is in this Hypotheſis an additional Character of Truth.

Equally and perfectly agreeable to Experience and Reaſon, it has beſides the ſingular Advantage of accounting for and explaining all the Alterations, which Religion teaches us have happened, or one Day or other will happen, in Nature.

When God keeps the Axis of the Earth directly placed on the Plane of it's annual Courſe, the Inhabitants of the Earth have but one Seaſon conſtantly the ſame, and enjoy both a long Life and a perfect Equality of the Air *. But he no ſooner inclines that Axis, but the Waters immediately overflow the Earth: Seaſons ſucceed each other on the Globe: The Unevenneſs of the Air ſhortens the Life of Men. It is ſcarcely the ſame Earth it was.

There is a Time known to God alone, when he ſhall give our Globe a ſecond Jerk. The Axis of it will no ſooner be put in Motion, but Men will ſee the Heaven run like a Roller, the Stars fall, and Nature ſeem in the greateſt Confuſion. That Fall of the Stars, and that Flight of the Heavens, are a Language worthy him who made Man, and who alone knows the Reaſons of the Appearances which he makes Man feel. Nothing more grand and majeſtic, nothing more exact than this Language. Men at the firſt Shock of the Earth, will neceſſarily ſee the Heavens change their Place and fly away, as they now ſee the Sun aſcend, and from the Top of the Firmament deſcend to the Point of it's Setting. *Copernicus* himſelf ſaw the Stars riſe and go down; and he ſaid with the reſt, *the Sun riſes, the Sun ſets,* without Fear of offending Truth. His Hypotheſis, which accounts for the Oeconomy of the World, becomes here the Interpreter of Scripture, and makes us clearly underſtand, that the future Alteration ſhall in all it's Circumſtances foretold, be as ſenſible as the actual Courſe of the Night and Day. It is a very rich Hypotheſis indeed, which proves to be equally agreeable to Faith, to common Senſe, and the moſt frequent and reiterated Obſervations.

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* See the Letter at the End of the third Volume.

The

The MICROSCOPE;

And the Other

INVENTIONS

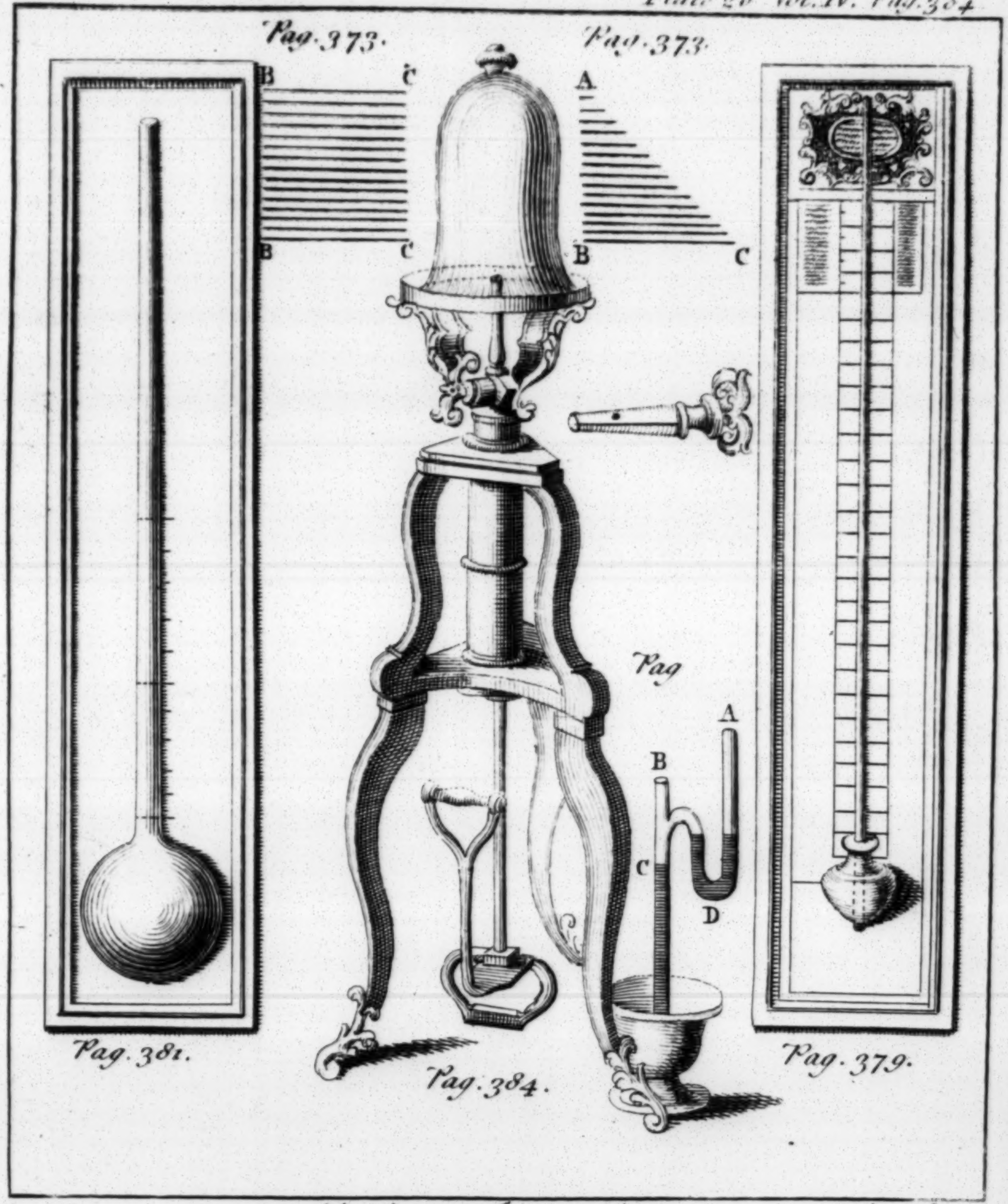
OF THE

MODERNS.

DIALOGUE VII.

THOUGH *Galileo* and his Diſciple *Torricellius*, were ſtill full of the falſe Notions of antient Philoſophy; yet they muſt be looked upon as the Fathers of modern Phyſics; ſince they were the firſt who dared to maintain the Rights of Reaſon againſt the Authority of *Ariſtotle*, which ſtopped the Progreſs of Sciences by tyrannizing in the Schools; and they firſt introduced the Method ſo agreeable to Reaſon, of making every Thing refer to Experience. Naturaliſts, till *Galileo*, were no better than mere Talkers. Ever ſince his Time, and after his Example, they all turned Obſervers; and it is on account of his having obſerved what had eſcaped the Eyes of all the preceding Ages, that the *Italians* ſtyled him the *Lynx-eyed Virtuoſo*.

Plate 26. Vol. IV. Pag. 304



Modern Inventions.

Toms Sc.

The Statics, both that which ſets Levers and Weights a-going, and that which gives Motion to Fluids, all Mechanics, Aſtronomy, and Phyſics in general, borrowed many conſiderable Helps from the Attempts made by *Galileo* on Motion, and by *Torricellius* on the Air. I ſhall be contented with giving you an Account of the two fineſt Diſcoveries of each of them. That of the firſt is the regular Acceleration of heavy Bodies in their Fall. I ſhall propoſe it to you after my own Method, and in as few Words as poſſible.

Of the Acceleration of heavy Bodies.

Let the Cauſe which brings down the Stone flung into the Air be what it will; it is an exiſtent Cauſe *. The Stone, at what Degree of Elevation ſoever it may be, receives the Impreſſion of that Cauſe. That which makes the Stone to fall, does then Influence it every where, and at every Inſtant after it has left the Earth. Let us now from Reaſon ſee, what will happen to a Stone caſt into the Air, in Conſequence of this very plain Principle. We ſhall be inclined to think ourſelves to have reaſoned well, if our Argument proves agreeable to Experience.

A Stone placed at twenty or thirty Foot Diſtance from the Earth, and left to itſelf, ſhould (one would think) neither aſcend or deſcend; ſince it has of itſelf no Inclination, or any Motion of its own. It moves only as it is puſhed. Its Indifference in the Choice of one Direction preferably to another, is ſtill augmented by the Equality of the Preſſure of the elaſtic Fluid of the Air, which, by puſhing it as much towards the Heaven as towards the Earth, and in every other Direction, ſhould for ever contribute to keep it in the ſame Place. However, we know, that there is a very active Cauſe, be it what it will, which puſhes the Stone downwards from above at every Inſtant, and at what Point of the Air ſoever it may be.

Any Body put into Motion, preſerves as much as poſſible the Motion it has got. The Stone will then, during the ſecond Inſtant of its Fall, and in all the following, as much as the Obſtacle of the Air ſhall permit, preſerve what Motion it has acquired in the firſt. But the ſame Cauſe which puſhed it at the firſt Inſtant, likewiſe puſhed it at the ſecond. It then adds a new Motion and a new Strength to the firſt, and its Swiftneſs in every Moment accelerated. The Proportion in which this happens is this.

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* See *Diſcorſi e Dimoſtrazioni Mathematiche, intorno alla mecanica ci movimenti locali del Signor Galileo Galilei linceo.*

Let us here repreſent Celerity with a Line. A Line conſiſting of only two or three Points, ſhall repreſent a very ſmall Acceleration, or a beginning Celerity. A Line conſiſting of a greater Number of Points, ſhall repreſent a greater Celerity. Thus, ſuppoſe that the Stone which begins to fall, receives in the Space of a Second *, an Impulſion ſufficient to make it croſs, for Inſtance, the Space of a Rod, Perch, or Pole fifteen Foot long; when it began to croſs that Space, it had not the ſame Swiftneſs which it has acquired when it had arrived at the End of that Pole. We may then repreſent the ſucceſſive Increaſes of that Celerity with 15 Lines, which always become longer from the firſt called A, to the laſt marked out B C. When the Stone ſhall have acquired at the lower End of the firſt Pole the Celerity repreſented by B C, it will preſerve this whole Celerity, and make uſe of it during the whole following Second. That Swiftneſs, which remains conſtantly the ſame during the ſecond Space of Time, may be repreſented by fifteen Lines of the ſame Value with B C.

Now theſe fifteen Lines marked out B C, B C, are evidently the Double of that which we marked out A B C; ſince they form the Square B C, B C, whereof A B C is but the Half. The Stone muſt needs then during the ſecond Second, have obtained a Swiftneſs twice as great as that which it has had during the firſt. It will then traverſe the Space of two Perches during the ſecond Time: But beſides this Celerity acquired and continued during the whole ſecond Interval, it contracts as much Swiftneſs as it did in the firſt, by the permanent Influence of Gravity, let the Cauſe which operates it be what it will. The Stone muſt then, beſides the Swiftneſs it then had, acquire in the ſecond Time the ſame Quantity of Motion as in the firſt Second; and by virtue of that Force croſs a Space equal to that which it croſſed at firſt, *viz.* another Perch.

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* The ſixtieth Part of a Minute, which is the ſixtieth Part of an Hour.

It muſt then, during the ſecond Second, croſs three Poles, two by the preſerved Celerity, and one by the Swiftneſs ſucceſſively acquired in the ſecond Time as well as in the firſt. The Stone, in moving during the third Second, retains the firſt Celerity acquired, which is as B C; and another Celerity newly acquired, which is again as the Line B C. We may now call the Celerity B C, a Degree. three or four Forces or Celerities, each of the Value of B C, ſhall be called three or four Degrees. If the Stone has, with a Degree of acquired Celerity, croſſed two Perches; now or in the Beginning of the third Second, that it proves to have acquired a ſecond Degree, it muſt croſs four Perches, and a fifth one by the Impulſion of Gravity, which, during the third Second, is as powerful and active as in the firſt Interval. The Stone has then, in the Beginning of the fourth Second, two Degrees of preſerved Force, and another newly acquired, which is three. If one Degree is ſufficient to make it croſs two Perches, three will be ſufficient to make it croſs ſix. The Stone will then, during the fourth Second, croſs a Space of ſix Poles, and the Space of a Seventh be obtained by the Impulſion of Gravity always perſevering. It will then, in the Beginning of the fifth Second, have three Degrees of Force preſerved, and one newly acquired, that is, four entire Degrees: Therefore it will, during the fifth Second, croſs through eight Perches, and through the ninth one by virtue of the ſucceſſive Impulſion of Gravity. It will be the ſame in Proportion in the following Times.

By this very plain Calculation, it is evident, that the particular Sums of the Spaces paſſed through, are one Perch or Pole for the firſt Second; three Perches for the next Second; five for the Third; ſeven for the Fourth, *&c.* In ſhort, the Sums of the Perches or croſſed Spaces are, from one Second to another, as the following odd Numbers, 1, 3, 5, 7, 9, 11, 13.

1st Second 1 Perch.	2d Second 3 Perches.	3d Second 5 Perches.
4th Second 7 Perches.	5th Second 9 Perches.	6th Second 11 Perches.

If afterwards, at the End of every Second, you collect the particular Sums of the Spaces croſſed by the Stone in that Second, with the Sums of the Spaces croſſed in all the preceding Seconds; you will find, that theſe total Sums are as the Squares of the Times. For if you join one Perch of the firſt Second, with the three of the following, they will make four: Now, four is the Square of two, or the Number two multiplied by itſelf. If you join the five Perches of the third Second with the four Perches of the two preceding Times, they will make nine: Now, the Number nine is exactly the Square of three; for three times three are nine. If you join the ſeven Perches of the fourth Space of time with the nine preceding, they will make ſixteen: Now, four times four make ſixteen. The total Sum of the Spaces gone through muſt then prove to be as the Square of the Times, or if you will, as the Square of the Celerities, which increaſe as the Times. What we have juſt ſaid of the Acceleration of falling Bodies, we may ſay in a contrary Senſe, of the ſlackening of whatever aſcends; becauſe the Force which raiſes it is inceſſantly diminiſhed by the Cauſe of Gravity. Therefore, if you throw a Body into the Air with a Force equal to the five Degrees of Celerity, which it ſhould acquire from Gravity in falling during five Seconds, and without taking Notice of the Acceleration, which in the Fall proceeds from the acquired Motion; that Body thrown will have but four Degrees of Celerity at the ſecond Second, three at the Third, two at the Fourth, and the remaining Force expires with the fifth Second.

What we have juſt eſtabliſhed by Reaſoning on the Acceleration of heavy Bodies, is not a bare Opinion. It is a Phænomonon for the firſt time obſerved by the celebrated *Galileo*, and confirmed by Experiments made at the Obſervatory, by the Help of the Hole contrived in the Vaults, from the upper Terraſs down to the Bottom of the Caves.

Of the Preſſure of the Air, and of the Riſing of Liquors in Pipes void of Air.

The Experiment which makes for the Glory of *Torricellius*, is the riſing of Liquors in Pipes void of Air. The Conduit-makers of the Grand Duke had bethought themſelves, to make Pipes higher than thoſe wherein Waters roſe as ordinary.

But as they did not experience from theſe Pipes of a new Structure, the Aſſiſtance expected from them, and the Pump refuſed its Service when the Water was to be raiſed above thirty-two Foot, they communicated the Thing to *Galileo*, and aſked him the Reaſon of it. Our Philoſopher for that Time was ſurpriſed, and unprovided of an Anſwer. However, he put a good Face on the Affair, and gravely replied, that Nature abhorred a *Vacuum* only to the Height of thirty-two Foot. The Conduit makers took this as a Principle; and that Rule, falſe as it was, for the Cauſe pretended, yet carried on their Works perfectly well, as to the expected Effect: So true it is, that a Man may, without any great Danger, be miſtaken with regard to the Cauſe of what he does, provided what he executes be directed by Experience. Experience is indeed our true Phyſics.

Torricellius *, vexed at the Water's refuſing to aſcend more than thirty-two Foot in a Pipe void of Air, made a new Experiment on a maſſier Fluid. He filled with Mercury a Pipe well ſtopped at one End; he ſet it up with the open End immerſed in a Veſſel of Mercury; then withdrawing his Finger, without putting the Orifice of the Pipe quite to the Bottom of the Veſſel, he ſaw the Mercury in the Pipe come down, and leave an empty Space at Top, and remain ſuſpended at the Height of twenty-ſeven Inches. How! ſaid he; Nature abhors a *Vacuum* only to the Height of thirty-two Foot when it is Water that aſcends in a Pipe void of Air, and only to twenty-ſeven Inches when it is Mercury? *Vacuum* does not frighten her beyond theſe Meaſures! But why does ſhe fear it to more than twenty-ſeven Inches, when it is Water that riſes? Very likely this Horror of Vacuity is an idle Fancy, a mere philoſophical Cant, which we take for good Coin without underſtanding it. Let us endeavour to find out ſomething better. His Spite and repeated Experiments led him at laſt to a very ingenious Conjecture. This Diverſity of Elevation in two very different Liquors, appeared to him to proceed from the Diverſity of their Weight. For, though neither he, or perhaps any other Philoſopher living, ever knew what

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* In the Year 1643.

Gravity is; yet it exiſts: It hurries us away: It cruſhes us: It is a moſt real Effect. As he was then ſearching what Weight might thus counterbalance theſe two Fluids, he thought Nature hinted to him, that a Column of Air, correſpondent to the Orifice of the two Pipes, might perhaps hinder the Fluids from falling, and kept them up at unequal Diſtances, becauſe the twenty-ſeven Inches of *Mercury* being very likely of the ſame Weight with thirty-two Foot of Water, which is a rarer kind of Matter, the Column of Air proved to be equivalent to either of theſe fluid Maſſes. This Conjecture, as well as the double Experiment of the Pipes, ſoon took Air, and ſpread abroad. Mr. * *Paſchal* improved the Experiments, and gave the Conjecture an Air of a Demonſtration. Nothing appeared to him more ſatisfactory than the Experiment made by his Direction on the *Pui-de-domme*, a Mountain near *Clermont* in *Auvergne*. The Column of Air being ſhorter at the Top of that high Mountain than it was at the Foot, he thought it ought to weigh leſs on that Account; and they found, that in Conformity to his Expectation, the *Mercury*, which at the Bottom of the Mountain maintained the Height of twenty-ſix Inches, was come down to twenty-three at the Top. Among other very ſenſible Means he employed a crooked Pipe, as you ſee it in the Figure. The End marked A, is hermetically ſealed up. The Orifice B is exactly covered with a Piece of a Bladder. The Pipe being full, muſt be turned up-ſide down as uſual. When you take your Finger from the End dipped into the Mercury, what will thence happen? If the Air weighs or preſſes, it will keep up the Mercury of the Pipe juſt at the Height of twenty-ſeven or twenty-eight Inches in C, and the Mercury which is in the crooked Part D, having no relation to the Air, will, on each Side, put itſelf in an Equilibrio in the two Branches. But if you open the Orifice B, the Air muſt precipitate the Mercury from the Pipe ſtraight into the Vaſe, and raiſe the Mercury which is in the crooked Part D, up to A. And this is indeed what happened in all the Trials made of it. However, I don't know whether it is perfectly certain, that this Effect of Fluids in *Vacuo* proceeds from the Weight of the Air. It has been ſince acknowledged, that the Air has a very powerful Spring, and that Spring poſſibly is the true Cauſe of what is attributed to the Preſſure of the Weight.

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* In the Years 1644, 1646, and 1648.

The Invention of the Barometer.

Some Virtuoſo's who had left in a certain Place a Pipe of this Kind, whoſe nether End was immerſed in a Veſſel of Mercury, ſoon perceived that the Mercury which was ſuſpended in the Pipe without falling out, was not always at the ſame Point; but that it roſe in dry Weather, and ſunk at the Approach of Rain, and ſometimes was ſuddenly agitated at the Approach of Storms. All theſe Obſervations were reduced into Rules. They put a Paper with Degrees marked upon it, or a Scale of ſeveral Marks towards the higheſt Part of the Fluid, in order to compare the Progreſs of it, and thence to deduce ſome Prognoſtics on the Changes of the Air. They thought they had found ſome that were pretty certain for the Space of one Day, which would be already of very important Service; and inſtead of the little Veſſel or Ciſtern ſeparate from the Pipe, they added to the latter a Glaſs Vial full of Mercury, making the Pipe ſomewhat elbowed or crooked, and keeping the Vial open at top, freely to receive the Impreſſions of the Air. As that Bottle was three or fourſcore times broader than the Pipe; if the Impreſſion of the Air by its Alterations make the Liquor of the Veſſel to deſcend one Point, there enters of Neceſſity a great many times as much into the ſmall Orifice of the Pipe; ſo that the riſing or ſinking of the Mercury in the Pipe, becomes thereby extremely ſenſible: In a Word, they found out the Barometer.

Many great Enquiries were made into the Reaſon why the Air, which one would think ought to be heavier at the Approach of Rain, ſuffers the Mercury of the Pipe to ſink, rather than to raiſe it higher by the Preſſure of that of the Veſſel.

To the common Conjectures I ſhall add one, which will at leaſt have the Merit of not being long. There remain always between the Tube and the Mercury poured into it, a great many Bubbles of Air, ſeveral of which fill the Top of the Tube after the Mercury leaves it.

Theſe Bubbles of Air are always the ſame in Quantity: But the Quantity of the Fire that creeps into or out of it may vary: They therefore may contract or dilate at the Approach of the Rain. The minute Drops of rarified Water, which every where ſpread, are ſqueezed and ſtopped by the Sides of the Glaſs. The Fire which gets out of them, eaſily inſinuates itſelf where the Water cannot enter, and dilates the Bubbles of Air it finds in the empty Part of the Tube, ſo as to preſs ſomewhat gently that Surface of the Mercury, which then yields and ſinks. The ſame Thing will happen, if you preſent a burning Coal to the upper Part of the Barometer; and if the Mercury does not ſink there in hot Weather, it is becauſe the Heat does not circulate leſs in the Air that preſſes the Mercury of the Veſſel, than it does in the Bubbles in the Vacuity. It is then probable, that the lowering of the Mercury at the Approach of Rain, is owing to the accidental Fire which inſinuates itſelf into the Bubbles of Air in the Pipe, by quitting the Bubbles of Water which are condenſed, on the outſides of the Glaſs. This Suſpicion ſeems to be countenanced by the ſmall Lightnings, which that Fire ſometimes cauſes, when the Barometer is jogged in the dark.

The Invention of the Thermometer.

A *Dutch* Peaſant named *Drebbel*, is reputed in the Beginning of the XVIIth Century to have had the firſt Idea of another Inſtrument, which commonly is annexed to the Barometer, and is called the Thermometer, becauſe it meaſures the Degrees of the Heat, as the other does thoſe of the Weight or Spring of the Air.

The Thermometer is nothing but a round Bottle, having at Top a very long and ſmall Neck or Pipe, whoſe inward Diameter is twenty, thirty, or as many Times as one thinks fit, narrower than the Body of the Bottle; ſo that if you cloſe the Pipe at the Lamp of an Enameller, after having filled the Bottle and a Part of its Neck with coloured Spirit of Wine, the Liquor cannot ſwell and mount one Point in the Body of the Bottle, without aſcending twenty or thirty Points in the ſmall Tube, Spirit of Wine is fitter than any other Liquor for this Purpoſe; becauſe it never freezes. The Fire which rolls in the external Air cannot increaſe therein, without inſinuating into whatever it meets with, and conſequently into the Liquor contained in the Glaſs Ball of the Thermometer. It cannot enter into the Body of the Ball, without dilating the Spirit of Wine; and if it dilates it ever ſo little, it ſenſibly cauſes the ſmall Thread of that Liquor to aſcend in the Tube. On the contrary, if the Fire leſſens either in Quality or Activity in the Body of the Air, it proportionably diminiſhes in the Maſs of the Spirit of Wine. This condenſes a ſmall Matter; and if the Diameter of the Ball is to that of the Tube as 1 to 20, the Liquor of the Ball cannot condenſe the quarter Part of one Line, but the Thread of the Tube ſinks at leaſt twenty Quarters of one Line, that is, five Lines. A graduated Scale, glued on Board wherein the Tube is ſet, ſhews the Dilatation or Contraction of this Liquor. But the Fancy of the Workmen being the only Rule that determines the Proportion of the Ball of the Tube, that generally determines the Point from which the Numeration is to begin: that alſo determines the Choice of a Liquor more or leſs capable of being dilated; that, in ſhort, aſſigns to the Degrees their Meaſure: The natural Conſequence of this Variety in the Conſtruction, is, that we hardly know what we ſay, when we mention ſuch or ſuch an Elevation of the Thermometer. It is ſelf-evident, that the Thermometer of two different Towns, or even Houſes, will never ſpeak the ſame Language; ſo that they can never be compared together.

Mr. *De Reaumur* *, by reducing the Conſtruction of the Thermometer to ſuch Rules, as make it uniform and conſtant, has enabled us to compare the Advices of the Thermometer of *Paris*, with thoſe given by the ſame Inſtrument at *Rome*, *London*, or *Conſtantinople*.

The Uſe of the Thermometer is not an Amuſement of mere Curioſity. It ſerves to determine the Degree of Heat we think fit to give to the Air of a Room, the Water of a Bath, and a hot Green-houſe; whether we intend to forward our ordinary Plants, or to preſerve ſome foreign Plants therein. This Inſtrument rules an infinite

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* See his excellent Memoir 1730. or the Explication found upon the Thermometers of that Conſtruction, at the Abbé *Nollet*'s in *Quai-Conti*.

Number of Experiments, wherein, we are exactly to judge of the Degree of Heat, of Fermentations, and of the Degree of Cold in what has been artificially frozen. In ſhort, it is moſt particularly from the Compariſon of Thermometers of an uniform Conſtruction, and placed in different Countries, that we may draw Conſequences fit to bring the Knowledge of the Air to its Perfection.

In order to judge rightly of the Variations of the Heat; the Thermometer muſt be put in a free Air to the North, and in Places inacceſſible to the Sun, to great Reflexions of the Light and the Heat of Chimnies. The North is likewiſe the moſt favourable Expoſition for the Barometer.

The Invention of the Air Pump.

There is another Machine deſigned to demonſtrate the Spring of the Air, and to inform us concerning the Relations that Element has with whatever breathes or vegetates; or rather with every and all the Parts of Phyſics. For is there any thing on Earth, into the Compoſition whereof Air does not enter, and makes its Action ſenſible? Is there any Element with which it does not unite? That admirable Inſtrument called the Pneumatic Machine, or more commonly the Machine of *Vacuum*, was invented in *Germany* about the XVIIth Century, by *Otho of Guerric* a Conſul of *Magdebourg*, and brought to Perfection in *England* by Mr. *Robert Boyle*, a Member of the Royal Society.

On a Stand of any Form, is horizontally placed a round Copper or Braſs Plate, with a Hole in the middle, garniſhed with a Buck or Sheep-ſkin, and deſigned to ſupport a Glaſs-cap, or any other Recipient you think fit to lay upon it. There is under the Plate the Body of a Pump, into which you receive the Air of the Recipient, as you let down the Piſton or Sucker. The Cock being turned, and exactly ſtopping all Communication of the Pump with the Receiver, lets the Air out through a Groove contrived at the Side of the Key. When the Sucker is raiſed up again, and the Air diſſipated, they open the Channel again, and by new Strokes of the Sucker, exhauſt as much as poſſible the Air from the Recipient, which the Preſſure of the Atmoſphere faſtens down very ſtrongly to the Plate; the little Air that remains under, being too much unbent to be able to reſiſt that Preſſure. You immediately ſee ſome Vapours floating therein, which are ſo many Particles of Water, wherewith the Air is always furniſhed, and which run together again for want of the Support of the Air, which by rarifying them made them alſo inviſible. If you put under the Recipient either withered Fruits, or a flaccid Bladder tied and loaded above with a Weight of ſeveral Pounds, the Skin of the Fruit ſtretches and becomes ſmooth: The Bladder ſwells, and makes the Weight riſe: A Bird or any other Animal immediately falls into Convulſions therein: A Fiſh experiences a moſt violent Tenſion: His Eyes ſwell, and his Air-veſſel burſts. The inward Air which dilates within their Body, becauſe there is no longer any Air that preſſes the Animal without, is to it at firſt in lieu of a violent Emetic, and would kill it, were not the Air immediately reſtored to it again.

From theſe and a hundred other Experiments it has been found, that the dilated Air fills a Space ſeveral thouſand times larger than it did when it was compreſſed. They have begun to perceive the Power of the Air, in all the Nutritions of Animals and Plants. But of all the Advantages that have been procured by this Invention, (and theſe indeed are numberleſs) none perhaps is greater, than that of perceiving the Artifice by which God has made us to live in a Fluid which we do not feel, by giving the ſmall Portion of the Air within us, a Tendency towards dilating, every whit as powerful as that the external Air has to cruſh us by a Preſſure capable of breaking the Ribs of our Bodies, and of ſuddenly bringing the Back and Breaſt-bone cloſe to one another. By this truly wonderful Equilibrium, the Muſcles which ſtretch the Arm of Man, and thoſe that move the Wing of a Gnat, exerciſe their Motions without any Reſiſtance, notwithſtanding the enormous Preſſure of the Body which is round them. And whenever that external Preſſure increaſes or diminiſhes by the Concurrence of the Water, the Fire and the Winds, there happen in the Veſſels of Animals and Plants, ſuch Alterations as determines the good or bad Conſtitution of them. All the Progreſſes of experimental Phyſic are then to us Demonſtrations of the two following Truths: The firſt is, that God maintains the World by the general Law of a ſimple and regular Motion; the other, that the very minuteſt Globule of Fire, Water, or Air, is a Machine framed with Art, and by a ſpecial and determined Will.

Both theſe Truths, the Baſis of ſound Phyſics, will borrow the utmoſt Degree of Evidence and Perſpicuity, from the Diſcoveries that have been made by the Aſſiſtance of the Microſcope.

The Invention of the Microſcope.

It is thought, that the *Hollanders*, who had with Succeſs wrought the Glaſſes that draw remote Objects near, were the ſame that firſt looked for, and found out ſome Means of magnifying Objects. Mr. *Hooke* in *England*, Meſſieurs *Salveti* and *Malpighi* in *Italy*, Mr. *Leewenhoek* in *Holland*, and Mr. *Joblot* in *France*, have applied themſelves very much both to the improving of lenticular Glaſſes and the Manner of mounting them; and have communicated a thouſand Obſervations to us equally curious and important. The Microſcopes which are the moſt approved for their Structure and Effects, are thoſe of Mr. *Edward Scarlet* of *London*, of the Abbé *Nollet*, and of Meſſieurs *George* at *Paris*. *Leewenhoek*'s famous Microſcopes were nothing but very ſmall Drops of Glaſs melted at the Lamp of an Enameller. When we want the Inſtrument, we may at any Time, and in a Moment, procure it to our ſelves, by piercing with a Pin a very ſmall Piece of Lead, and by filling the Aperture with a very little Drop of Water, which you are to put into the Orifice with the Beak of a clean Pen. If that Drop remains round like a Bubble in the Pin-hole, it becomes a Lens, the Focus whereof being extremely near it, will prodigiouſly magnify any ſmall Object you ſhall preſent thereto: And the Loſs of that excellent Microſcope may be repaired at a very ſmall Expence, by one that is equivalent, or perhaps ſuperior to it in Goodneſs.

Here, together with an unknown World, we diſcover new Motives every where to adore and be ſenſible of the Hand of the Creator. From a vague and extravagant Prejudice, oftentimes ſtrengthened by the very Principles of our Maſters upon the Subject of Corruption and Generation, we attributed to vile Matter the infinitely honourable Privilege of producing Animals and Plants. I never would call ſuch a Philoſophy a ſacrilegious Impiety; ſince we can never be too ſparing in the Uſe of odious Appellations: But to take from GOD, and to attribute to a Fruit grown ſour, the Glory of producing an Inſect, which ſhall afterwards bring forth its like, is ſaying, that Motion may organize a Body, prepare a Brain, make Nerves iſſue from it, conſtitute a Contraſt of Muſcles, conſtruct Lungs, a Heart, a Stomach and Bowels. Does not the Philoſopher who gravely teaches the Poſſibility of theſe Generations, thereby ſhew a perfect Readineſs and Diſpoſition to admit *Epicurus*'s Coſmogony? But inſtead of arguing here againſt the ſecond Cauſes of the Schools, and againſt their directive Concourſe; let us take a good Microſcope in Hand; it will confute all thoſe empty Formations which are attributed to Matter, and every where unveil to our Eyes the immediate Operation or Action of a Wiſdom which daily produces every thing, or from one Day to another unfolds what ſhe had in the Beginning created in little; that it might ſucceſſively again produce and perpetuate itſelf through all Ages for ever. The Microſcope ſhews us all theſe Inſects coming out of the Eggs that contained them. There are now a-days no Plants, whereof it does not diſplay the Seeds. The very Muſhroom has its own; and the Dung which may very well nouriſh it, can no longer generate it. Nay, ſomething more was done. The imperceptible Duſt, which from the Top of the Stamina of Flowers fall round the Tufts of the Trunk or Snout that ſtands on the Capſula of the Seeds, in the Microſcope become Bodies of a regular Figure, and conſtant in every Species. The Duſt of Mallows are little Balls briſtling with Prickles, like the Shell of a Cheſnut. The Duſts of Poppies are Balls wholly tranſparent, a ſingle black Spot excepted, where all the Threads of a fine Net-work, which ſurrounds them, do centre. The Scale of a Sole, the Smallneſs of which makes us to overlook it, and which we ſwallow without our Knowledge, is a Work of a raviſhing Regularity. The End which faſtens this Shell to the Sole's Back, is armed with twelve or fifteen ſmall Points, with which it is as it were pinned to the Fleſh of the Fiſh. There is not one ſingle Fiſh, whoſe Scales are not more beautifully woven, than the Maſter-piece of the moſt ingenious Baſket-maker. The Fibres which compoſe the Scale of a Pike,

Pike, are woven in a Manner quite different from thoſe which we admire in the Scale of a Carp or Perch: But one Order and Texture invariably reigns in all the Scales of the ſame Kind. No leſs Regularity is found in the Structure of the Feathers of Birds, in the Fibres of the Fleſh of the ſeveral Animals, in the Make and Compoſition of the ſeveral kinds of Wood, and in the Figures of the different Salts. From the *Cape of Good Hope* to *Suez*; from the *Iſthmus* of *Suez* to the remoteſt Parts of *Tartary*; in ſhort, from *Tartary* and *Labrador* to the *Terra Magellanica*, whatever exiſts has a conſtant Form, and an invariable Structure, notwithſtanding the Variety of Foods, and the Multiplicity of Circumſtances. The Mixture of the Species may indeed perpetuate and multiply ſome certain Varieties in the outward Form, and in the Inclinations of Animals. The Paſſage of the Duſt of the Flower of one Pear-tree, into the Piſtillum of the Flowers of one another, may alſo make a Mixture of Properties, and enrich us with ſome new kind of Fruits: But the Genius of both the Animal and the Plant is never to be deſtroyed, and the Motion of accidental Cauſes, which never alters them at Bottom, or entirely changes their Nature, can by no Means have formed the ſame. The Microſcope gives this important Truth a far greater Degree of Evidence, by enabling us to perceive Duſts and Grains in thoſe very Plants which are of themſelves imperceptible. This Uſe of the Duſts, employed in an uniform manner, to render the Seeds fruitful in all Plants whatever, ſhews a general Deſign; and the Variety of the Execution of it ſtill better ſhews, that this it not the Work or the neceſſary Impreſſion of blind Motion, but the Choice of a free Wiſdom, which has in ſuch or ſuch Plants united the Duſts and Seeds on the ſame Stem; and has in other Plants put the Duſts on one Stalk, and the Seeds on another: An Artifice which can indeed never be done by either Motion or Attraction.

The Microſcope, which in every known Being brings us from the ſame Veſſels to the ſame Fibres, and afterwards ſhews us the ſame capillary Fibres therein, convinces us of a primordial Delineation, and of an Organization, which, in the minuteſt Animal, as well as in a whole World, can have no other phyſical Cauſe than GOD himſelf.

This is not a Place to ſpeak to you of the Structure of Microſcopes, or of many other wonderful Machines, which are every Day invented. I ſhall defer giving you the Principles of them, till I entertain you about the geometrical and mechanical Rules, which make up the full Certainty of the ſame. It is impoſſible now to purſue a more particular Enumeration of the Succeſſes of Experimental Phyſics, either in the Aſſiſtances it endeavoured to procure our Ears and Eyes, or in thoſe it ſupplied us with, by the Obſervation of the internal Parts of the human Body. Chemiſtry alone ſhould deſerve to be ſtudied apart. One might make up a reaſonable Volume of the bare liſt of the Services which Botanics do us every Day, by ſhewing us new Remedies, by embelliſhing our Gardens with new Shrubs for Flowers, by enriching us with new Vegetables and Fruits, by facilitating the Means of keeping up our impaired Foreſts, by ſupplying Turners, Joiners, and Inlayers, with Woods of a richer Colour, or fit to be rendered more ſmooth, by ſupplying Painters and Dyers with Seeds, Gall-nuts, Fruits, Leaves, Woods, Roots, and Oils fit to bring Varniſhes to Perfection, and to diverſify the Ornaments which we like in our Attire, Furniture, and Churches.

A ſingle Fact will make you judge of the Merit of Botanics. A few Sprigs of Coffee, having with their Roots been carried from the Garden of the Plants of *Leyden* to *Java*, and from that of *Paris* to *Martinico*, and then to *La Cayenne*, have already begun to yield Millions, and almoſt wholly freed *Holland* from the Contagion of the Scurvy, by rendering the Uſe of Coffee univerſal and common there. But I ſhall give you a ſufficient Account of all the Helps which we derive from modern Phyſics, by acquainting you in in a few Words with the Eſtabliſhment of thoſe illuſtrious Societies, which profeſſedly make it their Buſineſs to procure us theſe Helps.

The Succeſs of the Obſervations and Experiments of *Galileo* and *Torricellius*, in the Time of King *Lewis* the Thirteenth, induced a Multitude of Virtuoſo's to attempt the ſame Things in *France*. The Exactneſs, quick Penetration, and ſingular Clearneſs of Mind of Mr. *Paſchal*, who carried the ſame Experiments much farther, cauſed him to be careſſed and courted by the greateſt Naturaliſts of that Time. As young as he was, Crowds of learned Men flocked together to hear him ſpeak. By degeees, a Society of Virtuoſo's gathered round him, who regularly held their Conferences on certain Days, and mutually communicated to each other the Fruits of their particular Studies. Next to Mr. *Paſchal*, the moſt conſiderable of theſe learned Men were Meſſieurs *Fermat*, *Robertval*, *Gaſſendi*, *Des Cartes*, Father *Merſenne*, a Minim Monk, and a few *Engliſh* Lords. Mr. *Oldembourg*, who was one of the latter, being returned to *London*, there introduced the Method of the like Conferences. This Aſſociation for the Improvement of ſolid and evidently uſeful Studies, eaſily found a good many Favourers among the *Engliſh* Nobility; not only becauſe they found therein Means of Comfort, or of avoiding Suſpicion under the Dominion of *Cromwell*; but above all, becauſe the Lords of that Nation look upon Ignorance as a Reproach; and never think themſelves happy, but in Proportion as they buſy themſelves uſefully and ſeaſonably. The ſame Encomium of the *Engliſh* Nobility was made by *Eraſmus* above two hundred Years ago.

The evident Advantage of theſe Societies, determined almoſt at the ſame Time, King *Charles* the Second, and King *Lewis* the Fourteenth, to render them durable and permanent, by giving the Royal Society *, and the Academy of Sciences †, a Houſe, a Fund, and proper Regulations. The Tranſactions of both theſe Societies are nearly ſo many annual Experiments; and it may be ſaid, that it is from them that we have our beſt Phyſics. After their Example, were ſucceſſively formed the Academies of *Florence* and *Boulogne*, of *Montpellier* and *Bourdeaux*, of *Leipſic* and *Berlin*, and of late thoſe of *Petersbourg* and *Seville*. Theſe two laſt make us hope to obtain the Informations which we wanted, both on the Particularities of the Northern Parts of *Europe* and *Aſia*, and on thoſe of both *America's*.

All theſe Societies gave, and every Day give, Birth to an infinite Number of painful Obſervers, who, inſtead of tediouſly repeating, or of diſguiſing with a new Outſide the Learning of their Predeceſſors, conſtantly proceed from one Experiment to another, and every Day afford new Facts and Truths heretofore little known. The Title of Geographer or Aſtronomer, of Botaniſt or Geometer, or any other, aſſumed by any Naturaliſt, who deſigns to have Admittance into the new Academies, is the Profeſſion of the Service he obliges himſelf to do the Public. By this means, Sciences, formerly ſo dull, ſo languid and melancholy, are now become as active, as briſk, and as ſtrictly adapted to our Wants, as Arts, even the moſt mechanical, can be.

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* In the Year 1663. † In the Year 1666.

We are indebted to Mr. *Huygens*, one of the Academy of Sciences, for the Perfection of Clock-making: Great *Caſſini* ſhewed us the Ring of *Saturn*, and four of the little Moons which attend it. The practical Part of Aſtronomy, which is of greater Concern to us than the moſt ſublime Theory, is now come in his Hands to a greater Degree of Exactneſs it had ever yet attained before him. In the Year 1663, Mr. *James Gregory* *, of *Aberdeen* in *Scotland*, gave us the Idea of the reflecting Teleſcope; and it is that which Meſſ. *Paris* now make with ſo much Succeſs, both in little and in great. Some Years after, Sir *Iſaac Newton* made us acquainted with the Wonders of Light. Mr. *Malpighi*, a Phyſician of *Boulogne*, is the firſt who rightly and accurately obſerved the progreſſive Unfoldings, both of the Chick in the Egg, and of the Sperm in the Seeds, and generally of the Stalk, of the Barks, and of the Buds in their *Capſulæ* or Caſes. Meſſ. *Morland* and *Geoffroi* are thoſe who, being guided perhaps by the Advices of *Seneca* and *Pliny*, have put in a better Light the Relation which is found between the Duſt of the Stamina, the Flowers of the Seeds contained below the Piſtillum.

Mr. *De Tournefort*, Mr. *Ray*, and Meſſ. *De Juſſieu*, have, by their indefatigable Cares, put in good Order the Knowledge of Plants, which was horribly confuſed before. Theſe two laſt, infinitely dear to the Public for the vaſt Extent of their exquiſite Learning and Knowledge, are ſtill more ſo on Account of their eager Zeal in forming good Philoſophers. Mr. *Lemeri* ſerved us extremely by his Dictionary of Drugs. Mr. *Pajot d'Onzenbray*, Mr. *Bonnier de la Moſſon*, Sir *Hans Sloane*, and the Duke of *Bourbon*, by their rich Collection of Curioſities, of marine and terreſtrial Productions, of mineral Matters, Inſtruments and Machines of all Kinds, have nobly animated and aſſiſted Natural Hiſtory, Mechanics, and all Arts in general. Their Cabinets are the true Magazines of Natural Philoſophy; and offer Virtuoſo's not only an amuſing Spectacle, but alſo a commodious Repertory of whatever may be ſerviceable to Mankind, excite Curioſity, and be the Subject-Matter of ſo many Experiments.

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* See his *Optica promotæ*, printed in the Year 1663.

The Deſcription of a good Obſerver.

It is not enough, my dear *Chevalier*, that I have informed you of the fineſt Diſcoveries of Modern Phyſics, and given you a Reliſh of that Science, which is fitter than any, nobly to fill up the ſpare Hours of a rational and judicious Mind. The Hiſtory I have given you would ſtill be inſufficient, did I not conclude it with the Picture of ſuch an Obſerver as may ſerve you as a Pattern. I know one of that Kind, and you know him too, ſince I have often obſerved to you, that if I had ſometimes amuſed you by certain and delightful Obſervations, I was particularly indebted to his Works for the ſame.

He is a Geometrician; becauſe he knows that no great Progreſs can be made in many Parts of Natural Philoſophy, without the Aſſiſtance of Geometry. But he is not upon Geometry for ever: He is not perpetually intent upon Lines; nor does he affect publickly to talk Algebra, with three or four *European* Philoſophers who may chance to underſtand him. When Neceſſity requires it, he has Recourſe to his Mathematical Caſe of Inſtruments; and, but in Caſes of Neceſſity, he loves to treat on ſuch Subjects as be univerſally underſtood. What he ſays about them is always ſo new, and uttered with ſo much Comelineſs and good Grace, that Ladies find a vaſt Delight in liſtening thereto. Nay, his Generoſity is ſuch, that he pitched upon ſuch Matters as may concern Artizans themſelves.

He is a great Obſerver, and his Learning is rather about Things of particular Examination, than about general Subjects, having from long Experience been convinced, that there is ſcarce any thing but Uncertainty and Unprofitableneſs in general Phyſics; whereas the Conſideration of particular Subjects, moſt commonly leads us to certain Diſcoveries and uſeful Operations.

Diffidence is the chief Character of his Method of obſerving. He carries the Exactneſs of his Reſearches to the utmoſt Scruple: And inſtead of being ſatisfied with one ſingle Fact, though he ſaw it very plain, he turns over and over, and every way conſiders the ſame Subject: He makes it paſs through ſo many Trials, that very often he by the way finds Things ſtill new, together with the Confirmation of his firſt Diſcovery. One might be apt to think, that ſuch a Patience muſt coſt a briſk Genius, and which is greedy of acquiring Learning, very much: But this Exerciſe has rendered him ſo very ſharp-ſighted in the Works of Nature, that he at the firſt View perceives, to what End ſuch or ſuch a thing tends, from the Analogy it has with other Things perfectly known to him. By the Beginning of an Experiment, he gueſſes what the Sequel of it will be. From the firſt Motions he ſees any unknown Animal to make, he foretels in what the whole Operation of that Animal will end. But though he is uſed always to ſee his Predictions accompliſhed; yet he never thinks himſelf to have ſeen any thing till he has repeated and varied his Experiments. He looks upon the minuteſt Things in Nature, as ſo many Miracles, which are not to be admitted, till they have been fully aſcertained, and made clear beyond all doubt.

The Aim of his Obſervations is, as far as in him lies, to make them refer to our Wants. I know that he ſometimes aims at no more than a laudable Curioſity. There is perhaps nothing more than a bare Amuſement to be hoped for, from what he tells us of the Formation of Pearls, Shells, and Stones, of the Beginning and Increaſe of Coral, of the Light which ſome certain Shells caſt *, of the Republic of the Waſps, and of the Work of a vaſt Number of Inſects: But Amuſements like theſe are indeed very noble; and even in theſe he may be ſaid to arrive directly enough at Utility; ſince reaſonable Diverſions make a Part of our Wants.

As for the reſt, this agreeable Virtuoſo every Minute has our Welfare in View. One would think, from his conſtant Attention to find out, whether ſuch or ſuch a Thing

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* The *Dails, Dactyli.*

might not be of Service for promoting the Fertility of Lands; whether another might not procure us ſome new Dye; whether a third might not be good for Iron-works; whether ſuch or ſuch an Earth might not imitate *China* Ware; whether ſuch or ſuch a Sand might not be of Uſe to Architects or Glaſs-makers; whether ſuch or ſuch Means might not aſſiſt a Houſewife or a Mother, in preſerving her Stuffs from Moths, or her Children from the biting of Bugs: From all theſe his Cares, I ſay, one might be apt to think, that he is aſhamed of knowing any thing which Mankind can reap no Benefit from. He never thinks himſelf debaſed by theſe minute and particular Cares. His Phyſics are not diſparaged or diſhonoured, becauſe he ſometimes happens to be with Blackſmiths, or in a Dairy or a Kitchin. He with Dignity teaches a Country-woman or a Farmer's Wife, how ſhe muſt with little or no Expence do an Egg over with a Lay of Varniſh, or put it in a little Mutton Fat, to preſerve it perfectly freſh for ſeveral Months together *. I ſhould be a thouſand times more pleaſed with myſelf, to have procured ſuch a wholeſome Food for the poor Sailors, than to have accounted for Electricity, by an Attraction which diminiſhes in an inverted Proportion of the Square of the Diſtance.

I could not, my dear Friend, better conclude this Hiſtory of experimental Phyſic, than by inviting you to imitate in this Study, as well as in all your Reſearches, the provident Cares and noble Views of Mr. *De Reaumur*. His Love for the Public (of which I am a Part) is moſt particularly what makes him dear to me. This Intereſt alone made me his Friend; and were he born in *London*, or beyond the *Alps*, the Eſteem and Gratitude I ſhould expreſs for his Works would be equally lively, but could never proceed from a purer Motive.

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* I have experienced, that a new-laid Egg, boiled as common, may be thus preſerved without any Alteration for a Month or more; becauſe the white Varniſh, thickened on the Pores of the Shell, hinders the Liquors from tranſpiring. When 'tis put again into boiling Water, as if it had never been done, it turns the White into Milk as well as at firſt. Which may be very uſeful for ſick Perſons, in the Months of *December* and *January*, and at all Times in Hoſpitals.

THE HISTORY OF Syſtematic PHYSICS.

DIALOGUE VIII.

THOUGH the Hypotheſis by which *Ptolemy*, *Copernicus*, and *Tycho Brahé*, have endeavoured to account for the Motions of the Heavens, be commonly called Syſtems; yet this is no longer what we underſtand by General and Syſtematic Phyſics. We have now in Hand thoſe Phyſics, which pretend to account for and explain the Original, and the inward Frame of the whole Univerſe. A noble Project indeed! Four or five renowned Philoſophers have buſied themſelves about it. They formed numerous Parties, and created many great Diſputes. The Hiſtory of their Pretenſions may perhaps determine us to ſide with the better Party, or to preſerve a perfect Neutrality.

Epicurus's Atoms.

Epicurus, having revived the Notions of *Leucippus* and *Democritus*, thought he had conceived very well, that Particles of Matter differently formed, after having ſubſiſted from all Eternity, had ſince a certain Time, been hooked one on another in *Vacuo*; that by moving, ſome in a ſtrait Line, others indirectly, they had gathered in many different Platoons, and formed Bodies and Intelligences; That the Liberty of Man was more eſpecially the Work of Atoms moved in an oblique Line: That therefore, Hazard had formed the Sun, peopled the Earth, eſtabliſhed the Order that reigns therein, and by one Mould framed both the World, and the intelligent Being who is the Spectator thereof *: That we were not to think, that the Sun was made to light us, or our Eye to ſee; but, that having taken Notice, that the Sun might ſerve to light, and our Eyes to ſee, we had applied the Sun and Eye to thoſe Uſes.

This ſublime Philoſophy was written in *Latin* Verſe by *Lucretius*, commented upon by the great *Scaliger*, and by learned Men of all Countries, tranſlated into all Languages, in order to rectify the Notions of Men upon——

I provoke your Impatience in the very Beginning of this Hiſtory, my dear Chevalier; and if our other Contrivers of Syſtems have nothing better to afford you, I ſee you very ready to excuſe me the reſt. But you would very much wrong the others, by judging of them from *Epicurus*. His Syſtem is little different from thoſe that are made at *Bedlam*, and the Inhabitants of *Abdera* did tolerable Juſtice to one of the firſt Raiſers of that fine Edifice †, when they ſent *Hippocrates* to him to cure his Brains.

Ariſtotle's World.

Ariſtotle and his Favourers, think the World compoſed of primitive Matter, which has, they ſay, no diſtinct Form, and is apt to receive any Form whatever; from which ſprung the four Elements, whereof all Bodies are compoſed, and into which they are all reſolved by a final Analyſis.

There is indeed ſome Difference between that primitive Matter in the Atoms: But *Epicurus* and *Ariſtotle* agree in this, that they firſt admit of a primitive or primordial Stock of indetermined Matter, capable of entering into States and Compoſitions of all Sorts.

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* ——— *Neve putes oculorum clara creata,*
Ut videant; ſed quod natum eſt, id procreat uſum.
Lucret. de rerum natura.

† *Democritus.*

Gaſſendus's World.

Gaſſendus reſumes *Epicurus*'s Atoms and *Vacuum*, therewith to conſtruct his World, with this Difference, that he puts them into the Hand of God to make them move according to the All-wiſe Views of his Providence. This Philoſophy never offended any Body in the Point of Religion, which it does not ſtrike at upon any Account. But here again you are to obſerve the ſelf-ſame Foundation of an uncertain Matter, which at firſt has nothing regular or determined in it, and which ſhall afterwards be apt to be converted into ſome Body or other, according as you ſhall think fit to handle, compoſe, or divide the ſame, and to collect it into other Maſſes again.

Des Cartes's World.

Des Cartes rejects the *Vacuum*, and will have every Space to be full in his World; though it be a hard Matter to make the Liberty of Motion agree with the perfect Exactneſs of the *Plenum*. His Manner of conceiving the Creation of it is this: Firſt *, God creates an immenſe Maſs of homogeneous Matter, all the Particles of which are hard, cubical, or at leaſt full of Angles. He afterwards imparts to theſe Particles a twofold Motion. He makes moſt of them turn on their own Centre, and ſeveral Platoons of them turn round a common Centre: And theſe he calls Vortices or Whirls of Matter. This done, the whole is executed according to his Notions: and from the Friction of theſe Particles worn out at their Angles, a very fine Duſt will be formed, which he ſtyles the firſt Element; or the ſubtle Matter, then a globular Matter, which he calls the ſecond Element, or the Light; and at laſt a maſſy ſifted Duſt full of Branches, which he calls the third Element, of which all Sorts of Maſſes are to be made. This *Chaos* thus coming out of God's Hands, according to *Des Cartes*, ranks itſelf in Order, by Virtue of the Continuation of the two Motions thereon imprinted by God, and of itſelf becomes a World like ours, *in which, though* God *has put no Order or any Proportion* †, (theſe are his very Words) *all the Things both general and particular, which appear in the true World, ſhall be perceived.*

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* See the Treatiſe of *Light* and the *Principia*.

† See the *World*; or the Treatiſe of *Light*.

Chymiſts,

The Principles of the Chymiſts.

Chymiſts, in order to enable themſelves to make Gold, and to prepare the Reſtorative which hinders us from dying, or at leaſt conſiderably lengthens our Lives, were obliged to ſearch into the Bottom of Nature; and thought they had found out, that Salt, Sulphur, and Mercury, together with a few other Ingredients, about which they are not as yet agreed, were indeed the immediate Elements of Metals, and of all Bodies; but that there was in Reality a primitive Matter, which took all Sorts of Forms, as all the Sages of *Egypt* and *Greece*, and the Philoſophers of all Ages aſſured us there was: That conſequently nothing remained to be done, but to work upon that primitive Matter, to preſent it with fit Moulds, and to give it a certain Turn, to have Gold, Jewels, and the *Elixir Salutis.*

Hitherto, Sir, you ſee a perfect Agreement among all theſe Sects of Philoſophers as to the principal Point. They all, though under different Terms, come to a *Chaos* of primitive Matter, and of innumerable Particles which are neither Gold or Silver, Salt or Sperm, Fruit, or any other determinate thing, but which will ſerve by their Mixture to compoſe every thing, and into which every thing may at laſt be reſolved. The only Difference I find between them on this Account, is, that the Chymiſts are far more judicious than all the reſt, and make a much better Uſe of Wiſdom. The *Ariſtotelians* and *Corpuſculiſts*, are always ready to pull one another's Eyes out, about the *Plenum* and the *Vacuum*, Matter and Form, the Principles of Bodies, and the laſt Term of their Decompoſitions; and all this to no Manner of Purpoſe. They quarrel about the beſt Method of ordering Matter, as if the Queſtion was, to create the World, or to govern it. It is already made, and goes on in it's Courſe without them. The whole Sum of their Learning does then amount to the Art of filling Schools with Diſputes, from which we reap no Benefit. Chymiſts go much more directly to their Point, and argue thus: According to *Ariſtotle*, *Epicurus*, *Gaſſendi*, and *Des Cartes*, Gold and Sand are at Bottom but one and the ſame Matter: Great *Des Cartes*, by wearing out the Angles of his Cubes, ſaw the Sun, the Gold, and the Light itſelf, ſpring out of their Duſt: Let us ſtir up the Sand: Let us bruiſe the Corners and Angles of it, by the Force of Fire and repeated Frictions: Let us rob it of that accidental Form which makes it Sand; and by giving it a certain Turn and a happy Form, let us at laſt bring it to be Gold. What Riches, what Helps will this Metamorphoſis be to Mankind, if we can but once come at it!

If all ſyſtematical Philoſophers think rightly on the Article of primitive Matter, about which they all agree; Chymiſts think ſtill better, in reducing all theſe Speculations into Practice, and in endeavouring to bring that Matter to the happy Degree, which will make them fetch Gold and Immortality from it.

By a Misfortune fatal to the Glory of Philoſophers, Chymiſts not only die, but even live not ſo long as other People. Moſt of them dry themſelves up among Furnaces, and in peſtilential Exhalations: But they all infallibly ruin their Fortunes. The Unprofitableneſs of their Attempts is a Demonſtration of the Falſity of the Principle which they borrowed from Philoſophers, and authorizes us not to enter into a tireſome Examination of all theſe imaginary Phyſics. Life is too ſhort, and we have too many Duties to diſcharge to loſe our Time about ſuch frivolous Studies.

To be fully ſenſible of the great Miſtake of Philoſophers, it will be ſufficient to know that they frame the World of an unformed Matter, which at firſt was neither Water or Fire, or Metal, or Earth, or any thing that we now ſee, and which afterwards by Motion becomes whatever we do ſee. Conſtant Experience ſhews them all, if they be but willing to open their Eyes; that in order to procure the unfolding and growing of the tranſitory Species, which maintain the Scene of the World thoughout all its Ages, GOD has prepared a Multitude of ſimple and uncompound Natures, which never ſprung out of a primitive Matter different from themſelves: That theſe Natures have no other immediate Cauſe of their Formation, but GOD himſelf: That they never paſſed from a firſt State into a ſecond: That they are as invariable as he himſelf, who gave them their Being. That no Motion could ever alter or change them, or convert them into other Natures, or, in ſhort, reſolve them into any thing but what they are.

They are equally indeſtructible and ingenerable; and ſince the moſt violent Motion now-a-days is not capable of producing any thing in them; they are not indebted for their ſpecial Nature to any Turn or Diſpoſition communicated to them by Motion. Of this you will judge from a few Inſtances. Take ſome refined Gold, and put it in the briſkeſt Fire, it will remain melted, and in a State of Fuſion for whole Months together. A violent Fire, which, according to the *Carteſians*, is only a violent Motion, ſhould indeed, on this Occaſion as well as in the Beginning of the World, cauſe ſome ſmall Novelty or other in that Matter. It is certainly eaſier to deſtroy than to form. Why then cannot Motion, which fetched Gold from the primitive Matter, by it's ſeveral Degrees and Variations, deſtroy that Gold in the Crucible, or convert it into ſome new Being, or at leaſt reſolve it into a ſmall Parcel of Primitive Matter? How can Philoſophers not ſee, that they miſtake the methodical Notions, according to which every Thing is ordered in the Schools, for Realities ſubſiſting in Nature, while they exiſt only in their own Brains? They firſt think of Matter in general; then of determinate and ſpecial Matters: But muſt that make them believe, that there is or ever was a primitive Matter? They are admirable indeed, to look for the Analyſis of Gold, and to reſolve it into it's Principles, in order to bring it at laſt to the primitive Matter. They had as good analyſe Flowers in the Chymical Furnace, in hopes of finding in the laſt Decompoſition, a general Flower at the Bottom of the Recipient.

Likewiſe put on a violent Fire, Sand, Mud, Mercury, or any Metal you pleaſe. The Sand ſhall become Glaſs, by the Coherency it contracts in the Fire; and after having been whole Years together in the Glaſs-maker's Pot, it ſhall ſtill be, and for ever remain, Glaſs. The Mud ſhall fall either into Lime or Aſhes, and after the Diſunion, ſhall never be any thing but Aſhes and dead Earth. The Mercury mixt with Sulphur and all the Drugs imaginable, ſhall become Cinobar, or aſſume ſome other Form. It may have diſappeared, but has never been deſtroyed or changed. It is conſtantly entire under theſe new Forms, and always the ſame; and the Fire will return it to you ſuch as it was at firſt. It is the ſame thing with Metals. Torture them; give them whatever Motion or Alteration you may think poſſible by Fire, Aqua-fortis, or any other Diſſolutions; they have not changed their Nature; not even a ſingle Inſtant. If you put a Sheet of Iron in Aqua-fortis, which has already diſſolved a certain Quantity of Silver, it cannot ſupport the Particles of both Metals at once: It returns you the Silver entirely, which ſinks to the Bottom of the Veſſel, and which you by Miſtake thought to have been tranſformed into Liquor. It was only hidden therein, by rolling on the Globules of the Liquor, and by the Diviſion of the metalline Particles. But theſe Particles are in little what they are in a Maſs. The Minium or Red Lead with which they colour the Wafers for ſealing Letters, is made of Lead. The Metal is no longer ſeen: One would be apt to think it deſtroyed, or to have been converted into another Nature. It is only more divided there; but it's Particles never change; and if you offer ſuch a Wafer to a burning Wax-candle, receiving the Aſhes of it on a Paper; you will there ſee all the Particles of the Lead put in Fuſion, collected into ſmall Streams, and forming, as they grow cold, ſeveral ſhining Branches, eaſy to be diſcerned, even without a Microſcope. The Gold and Metals which are extracted from the Matters where nothing metalline appears, are not formed there. They are only found in thoſe Matters, and we extract them from thoſe Places whither they had been carried and diſperſed before. Hence the Gold found along Rivers and in Sands: Hence the Particles of Iron, which adhere to the Knife touched with a Load-ſtone, with which you rake up the Aſhes of Plants, or the Aſhes of the Fleſh and Intrails of Animals. Thoſe metalline, ſaline, earthly, ſandy, aqueous, fiery, and mercurial Particles, and ſeveral others equally ſimple, are toſſed about here and there, form Maſſes, appear under many very different Dreſſes, hide, and then ſhew themſelves again. But the Gold, the Iron, the Earth, the Water, the Sand, the Fire, the Mercury, in ſhort, all ſimple and uncompounded Matters, are conſtantly the ſame both in little and large. Theſe Natures are each of them it's own reſpective primordial Matter: And as the moſt violent and moſt varied Motion cannot reſolve them into any thing but what they are, of courſe they are not for their Sructure indebted to any Motion, either direct, oblique, or circular. All of them, as well as the whole World, came immediately out of the Hands of God himſelf. They are not indeed what they become by the Combinations of Motions; but what God from the Beginning was pleaſed they ſhould be, to ſerve for the Formation of thoſe compounded Bodies, for which his Wiſdom deſigned them. Gold and Cryſtal are no longer made: They only are carried, toſſed about, gathered or diſperſed. Motion therefore, which never was able to produce the leaſt Grain of theſe Matters, much leſs was capable of producing an Earth, or it's Inhabitants, or an Atmoſphere, or a Sun. Motion preſerves the World, but could never adjuſt it: Like as the Spring of a Watch, and the Care we take to wind it up every Day, makes it move regularly, but could never conſtruct it. It is then the Part of a conſiderate Naturaliſt, to ſtudy the Motions which maintain Nature; ſince they are real, regular, and conſtant: But attributing to the Motions imprinted on Matter the Power of forming a World, is to contemn Experience, and perhaps tacitly to revive the *Epicurean* Reveries. It is every Whit as impoſſible for Motion to form a World, as it is evidently impoſſible for it to form a Grain of Iron.

If we can get nothing but Loſs of Time, by raking up *Gaſſendi*'s Atoms, or in making *Des Cartes*'s angulous Bodies to whirl, we perhaps ſhall meet with better Succeſs, by having recourſe to the attractive, centripetal, and centrifugal Powers of the Northern Philoſophers.

The Difference between Mr *Des Cartes*'s Syſtem and Sir *Iſaac Newton*'s, is, that the former pretends to account for every thing; whereas the latter, modeſtly owning that we know not the Bottom of Nature, aims at no more than to clear a Matter of Fact, without pretending to account for the Cauſe thereof. But as that ſingle Fact, according to his Notions, takes in whole Nature, his Syſtem does thereby become a Sort of general Phyſics. According to Mr. *Des Cartes*, that Gravity which cauſes Bodies to fall, is not different from the Action of thoſe Fluids in which Planets are carried away; becauſe every Body which is moved, and by the ambient Bodies obliged to deſcribe a circular inſtead of a ſtraight Line, inceſſantly endeavours to recede from the Centre. Whence it happens, that when the Parts of the *Vortex* meet with Bodies that have no centrifugal Force, or that have it in a leſs Degree, theſe are forced toward the Centre; ſo that the Precipitation of heavy Bodies towards the Centre, is only the Action of more active Bodies having a Tendency to avoid it.

Sir *Iſaac Newton* firſt thinks, as well as Mr. *Des Cartes*, from whom he had learned it, that any Body will continue in its State of Repoſe or of Motion, till ſome new Force takes it, or makes it to deviate therefrom.

Sir *Iſaac Newton*, in the ſecond Place, thinks he has obſerved in whole Nature, (and this is the diſtinctive Point of his Syſtem) that all Bodies are attracted towards each other, in Proportion to their Diſtance and reſpective Maſſes: That they tend towards, and gravitate or weigh upon each other: That the Sun tends towards the Earth, and the Earth towards the Sun; but that the latter being incomparably bigger, the Approach of the Earth towards the Sun is alone perceived: That likewiſe the Earth tends towards the Stone which was ſeparated from it by Projection, as the Stone reciprocally tends towards the Earth. Or rather, that the Stone attracts the Earth towards itſelf, as the Earth attracts the Stone; but that the Earth having, on account of its Bulk or Maſs, an attractive Power infinitely greater than that of a ſmall Stone, it thence happens, that the Earth quits not its Place, and it is the Stone that comes towards it, or is dragged away, by the attractive Power which the Earth exerts thereon.

This mutual Action, which Sir *Iſaac Newton* thinks he perceives between one Body and another throughout whole Nature, he calls *Attraction*, and propoſes it as an Effect which is found all over the Univerſe, without being able to aſſign any other Cauſe for it but the Will of GOD, who appointed it to ſet whole Nature a-going. Therefore the Earth now moved round the Sun (were it only moved, not attracted towards it) would recede inſtantly from it. The Moon, did it obey without any Obſtacle the Law of the Motion which carries it away, would avoid and ſhun the Earth, and at laſt diſappear. Likewiſe, if the Earth did only obey the Law of Attraction, that is, the Law whereby the Sun attracts the Earth to itſelf, it would draw near and precipitately ruſh upon the Sun. The Moon being merely attracted, would fall upon the Earth. But if the Earth, being moved and thrown far from the Sun, is at the ſame time attracted by it; inſtead of receding from it in a ſtraight Line, that Line will be curved by the Attraction which brings it again towards the Sun. Being always influenced by two Powers, one of which draws it from, and the other attracts it towards the Sun, it deſcribes round the latter a curve Line, which Sir *Iſaac Newton* demonſtrates to be neceſſarily elliptic, or ſomething oval. The Moon, likewiſe, yielding to the Force which makes it fly off from the Earth, and at the ſame time to the Power which attracts it towards the Globe, circulates round the Earth. The centrifugal and the centripetal Force are mutually curbed by each other; and the Moon, inſtead of being hurried away from us by the firſt Power, or precipitated to our Earth by the ſecond, is, by the Impreſſion of both at once, retained within its Orbit.

Sir *Iſaac* examines afterwards, what ſhould be the Meaſure of the Motion of the Moon beginning to fall on the Earth from the Top of its Orbit, after having loſt its centrifugal Force, and having, as it were, been given over to the whole attractive Force which the Earth exerts upon it. The Diſtance of the Moon from the Earth is known: We know likewiſe the Time of its Revolution: We therefore may know, what is the Portion of that Orbit for one ſingle Minute. Geometry informs us, what Space the Moon would go through in a ſtraight Line, falling towards the Earth, by virtue of that Force which makes it paſs over that Arch or Segment of its Orbit. Having afterwards proved, that Attraction diminiſhes in Proportion as the Square * of the Diſtance increaſes; Sir *Iſaac* by his Calculations, finds, that the Moon, falling from the Place where it now is, would firſt go through fifteen Foot in one Minnte; and that near the Earth it would, by virtue or the ſame Law, in one Minute, go through a Space of three thouſand and ſix hundred times fifteen Foot. Having at laſt examined the Spaces which a Maſs of Wood or Stone goes through near the Earth, when let fall thereupon; he concludes from what Experience ſhews from the falling of Bodies, that a Stone in the Neighbourhood of our Globe, would in one Minute go through a Space of three thouſand and ſix hundred times fifteen Foot. The Moon let go from its Orbit, would then obey the ſame Law which precipitates the Stone. By a neceſſary Conſequence, if the Stone was carried as far as the Orbit of the Moon, and thence let fall on the Earth, it would go through a Space of fifteen Foot there. Attraction is then the ſame thing as Weight.

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* They call a Square any Number multiplied by itſelf. If the Interval from the Earth to the Moon be divided into three Strata's; the *Stratum* 1, has for its Square 1. The *Stratum* 2, has for its Square 4; and the *Stratum* 3, has for its Square 9. The Attraction, which diminiſhes in Proportion as the Square of the Diſtance increaſes, ſhall then act as 9 in the firſt *Stratum*, as 4 in the ſecond, and as 1 in the third.

Mr. *Privat de Molieres*, a Member of the Academy of Sciences, has in his phyſical Inſtructions preſerved the Ground of Sir *Iſaac*'s Obſervations. He admits of all the Proofs which ſhew, that the ſame Cauſe which makes a Stone to gravitate on the Earth, makes the Earth to gravitate upon the Sun, and the Moon upon the Earth. But he aſcribes that Effect to a Cauſe very different from that imagined by Sir *Iſaac*. The *French* Philoſopher, while he admires the Exactneſs of the geometrical Syſtem of the learned *Engliſhman*, at the ſame time thinks it inconſiſtent with the whole Plan of Nature. He is ſhocked by a Principle, which makes our World a Totality, whoſe Parts are more lank and incoherent than thoſe of a Skeleton. All the Notions we have of Mechanics, ſeemed to him quite demoliſhed by his ideal Attraction, which, according to the Favourers of the *Engliſh* Geometry, is reciprocally exerciſed among Bodies ſeparated by an immenſe *Vacuum*, and which makes them revolve in nought, without uniting them by any intermediate Bond. Mr. *De Molieres* reſumes Mr. *Des Cartes*'s *Vortex*, whoſe Exiſtence appears to him almoſt palpable in Nature. He mends that whole Syſtem, and by concluding from the very Structure of the *Vortex*, all the Effects perceived by Sir *Iſaac Newton*, he in a manner reconciles the two antagoniſt Schools.

That *Vortex* is no longer compoſed, as Mr. *Des Carte* thought it, of hard and inflexible Balls; but of many ſmall Vortices, whoſe Particles inceſſantly incline to recede from their own Centre; while the whole tends towards receding from the common Centre. A maſſy Body like the Moon or the Earth, thrown into that *Vortex*, muſt needs be preſently moved thereby, and carried away in the Direction of the whole *Vortex*. But the Parts of that heavy Maſs being ſtrictly united, and at Repoſe one by another, of themſelves make no manner of Efforts to move, and have no other Motion than the Impulſion which the whole Body of the Planet receives from the *Vortex* in which it ſwims: Whereas the Balls of the *Vortex* have a double Motion, and make a double Effort. They all tend towards receding from their common Centre, ſo ſoon as they are moved and forced by the ambient Vortices to move in a circular Line. Beſides, all the Particles of theſe Balls do in little round their own Centre, what the Balls themſelves do in general round their common Centre. From this double Tendency there reſults a double Force, which draws them from the Centre more powerfully, than the Motion imprinted on the Planet draws it from the Centre of the Sphere. The Planet, when thrown into the *Vortex*, has indeed therein received a centrifugal Force, by receiving a circular Motion. But its Parts being in Repoſe, it has a leſs centrifugal Force than the *Vortex*, in which this Force is double, both from the Motion of the minute Vortices which fly from the common Centre, and by the Particles of the minute Vortices, which at the ſame time fly from their own Centre. This Exceſs of centrifugal Force in the Matter of the *Vortex*, over and above the centrifugal Force of the Planet, muſt needs prevail. The Planet having a leſs Tendency towards receding from the Centre, than the Matter which puſhed it that way, it will thence happen, that the Earth will by degrees draw near the Sun, and the Moon fall on the Earth. In ſhort, Mr. *De Molieres* employs but one ſingle Action, or one ſame Cauſe, to form the centrifugal Force of the *Vortex*, and to make the Planets and all maſſy Bodies gravitate towards one and the ſame Centre; whereas Sir *Iſaac Newton* adds to the Motion imprinted on all theſe Bodies, another Power or Law,

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Fig. 2.

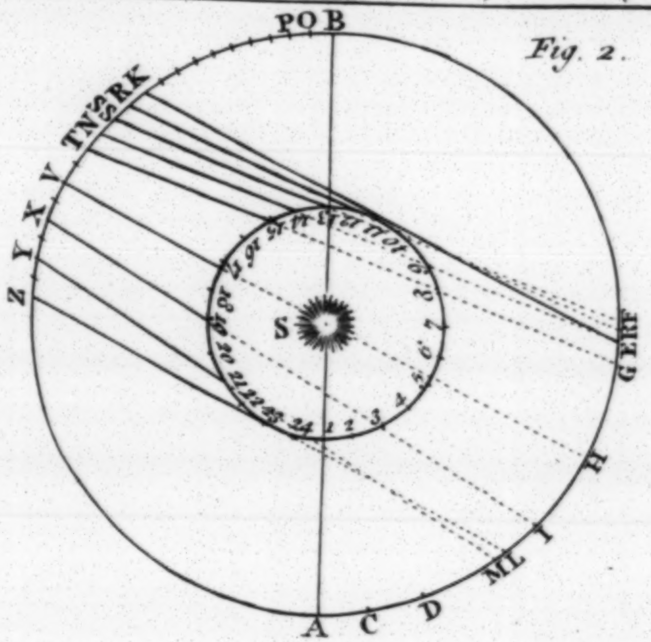
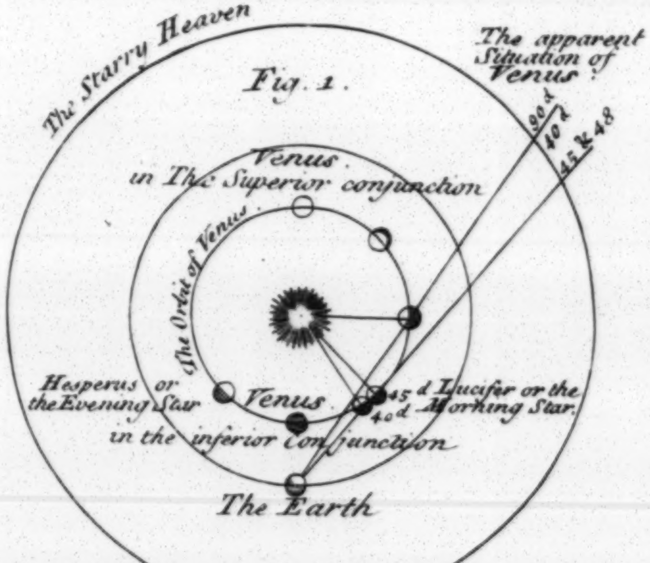


Fig. 1.


The Starry Heaven
The apparent Situation of Venus.
90 d
40 d
45 K 48
Venus in The Superior conjunction
The Orbit of Venus.
Hesperus or the Evening Star
Venus
in the inferior Conjunction
45 d Lucifer or the
40 d Morning Star.
The Earth

The Motions of the inferior Planets.

Ja. Mynde Sculp.

Law, which he calls Attraction, and which inclines them all towards drawing near each other more or leſs ſwiftly, in Proportion to their Maſſes or Diſtances, while there is no need at all of this ſecond Power, and it is impoſſible to conceive it.

Mr. *De Molieres*, after having, by his ingenious Explanation of Gravity, helped us to conceive the two-fold centrifugal Force of the Vortices, and the re-approaching of maſſy Bodies towards the Centre, as a ſimple Effect of that Force, ſtill leaves us in the Expectation of what he will introduce, to ſuſtain the Planets in their Orbit, and to hinder them from falling to that Centre. But it is eaſy to foreſee, that in the Leſſons which he is now preparing for us, he will make uſe of many different Vortices, or at leaſt ſeveral Atmoſpheres thrown round the Planets, to make them roll one upon another without falling; like Balls of different Matters, which preſs and flatten one another a little in rolling over each other, while the Centres which tend towards one another by the Impulſion of the ambient Vortices, are however unable to draw near each other.

This Explanation of Mr. *De Molieres*, when applied, not to create the World, but to conceive the Motions and Preſervation thereof, is the more acceptable, becauſe it may alſo be of Uſe in the particular Explication of a Multitude of Phænomena, and of particular Caſes. Such are, for inſtance, the Flux and Reflux of the Sea by the Preſſure of the Sphere of the Moon on that of the Earth; the diſordering of the Satellites of *Jupiter*, by the Preſſure of the Sphere of *Saturn* on *Jupiter*'s; the Attractions and Repulſions of electric Bodies, by the ſmall Atmoſpheres, which they acquire or loſe, as they are touched one way or another; the Chymical Diſſolutions and Fermentations, by the Diverſity of the Forces of the ſmall Vortices which compoſe the Liquors, and which can never appear at reſt, but when they have put themſelves in Equilibrio after a long Agitation, occaſioned by the Inequality of the Efforts.

The Inutility of Syſtems.

I ſhall take care here, not to enter upon a particular Account of the Syſtems imagined on Gravity by Meſſ. *Huygens*, *Bulfinger*, *Bernoüilly*, and many others.

This is only a ſingle Point of the Mechanics of the Univerſe. Aſk the Explication of it from fifty Naturaliſts, they all will think themſelves to have given you a Scheme of Phyſics, the more valuable in Proportion, as they ſhall uſe more Calculations and Geometry therein. But the Diſtance between Arithmetic and Geometry, and Phyſics, is often very great. All theſe indefatigable Calculiſts, and even often ſetting out from the ſame Point, will lead you to very different Sums, to very different Mechaniſms, and to as many Syſtems as there are Heads. What will then happen, when from this Point we would paſs on to the Explication of the Mechaniſm and intimate Structure of the other Parts of the Univerſe? Entering into theſe Syſtematical Opinions would be quitting the *Spectacle de la Nature*, and loſing Sight of the certain Uſe we may make of it; in which our true Phyſics conſiſt. Another Reaſon which ought to make us entertain a Jealouſy of Syſtems, is, that though they ſhould appear ever ſo grand at firſt ſight, the Application we are willing to make of them to particular Effects, moſt commonly proves abortive and ridiculous. For inſtance, make uſe of the Syſtem of Attraction, to explain the Phænomenon of the Load-ſtone, where it ſeems it ſhould be of very great Uſe; or to explain Electricity, or to account for what they call Fermentation; you will find that the Principle will fail you every where, and give you Intelligence of nothing. One is ſoon obliged to vary the Attractions as well as the Effects. Here you have an Attraction which operates in the whole Depth of the Maſs; there you have another Attraction, which operates only through the ſlighteſt Surface of Bodies. There is a certain Attraction, which is conſtantly the ſame, whether the Bodies be thick or thin, while another Attraction varies according to the Bulk or Thickneſs of the ſame. The Attractioniſts were chiefly in Love with that which they ſaw, or fancied they ſaw, in electric Bodies. It could not be miſtaken; and it operated exactly as in the Planets, diminiſhing round about as the Diſtance increaſed. By Misfortune, an experimental Philoſopher came and overthrew all this ideal Building; and by faſtening a ſmall wooden Ball at the Extremity of a Cord eleven or twelve hundred Foot long, he has found, that if one ſhould preſent an electrical Tube to the middle, or even the beginning of that long Cord, the ſmall Particles of Gold placed at the other Extremity under the wooden Ball, would apply themſelves, and as quickly faſten to it, as if the Electricity had acted at a Foot diſtance from the Tube. One of our moſt learned *Newtonians* * has made a thouſand Experiments upon the Loadſtone; and after infinite Cautions and Calculations, he frankly owns, that Attraction failed him when he wanted it, and that he could underſtand nothing in it.

I ſhall, my dear *Chevalier*, here conclude this Hiſtory of Syſtematical Phyſics, you needing not that I ſhould for the preſent give you a more extenſive Account of it. It will always be Time enough to reſume theſe ſublime and but little neceſſary Speculations. It would even be dangerous at your Age, and perhaps at any other, to prepoſſeſs you with any particular Syſtem; to which you infallibly would, either willingly, or whether you would or not, make every Phænomenon to refer: Which is an infinite Diſadvantage to the Progreſs of true Phyſics; either becauſe you never get out of the Circle of ſome certain Generalities, or becauſe you ſee every Thing merely according to your own Prejudices. This then brings you back again to Experimental Phyſics. It is indeed the only Philoſophy that ever was of any Uſe to Mankind; and I have already ſhewed you, that theſe Benefits were without Number. But could you ever, in purſuing the Study of Phyſics, follow a wiſer or more judicious Method than that which Meſſ. *de l'Academie des Sciences* always followed in teaching it us? They never approved in a Body of any general Syſtem. They are convinced, that if Man can any way be allowed to arrive at the intimate Knowledge of Nature, he cannot obtain it otherwiſe than by a long Series of Experiments and Facts for many Years together; and that if on the contrary that perfect Knowledge of Nature is for ever interdicted to our preſent State and Condition, at leaſt the Experiments and the Knowledge of Particulars will not fail, as we daily experience, to procure many real Services to Mankind. This infinitely judicious Principle, which has been a ſtanding

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* Mr. *Muſchenbroek.*

Rule to them, and the Nature of the ſeveral Functions which theſe learned Men have divided among themſelves, are exactly and equally grounded on our Wants and the Meaſure of our Capacity. Nay, more: Experimental Phyſics, to which they procured a vaſt Credit, is the only uſeful Syſtem, becauſe it is the only one agreeable to our Condition, which we may, without any Riſk, call the Syſtem of Providence.

An Experience of ſix thouſand Years is fully ſufficient to inform us of what is either acceſſible or interdicted to us. So long as Man, in his Reſearches, has buſied himſelf about what is ſubmitted to his Government, his Efforts were always rewarded with new Diſcoveries: But ſo long as he preſumed to dive into the intimate Structure of the ſeveral Parts of the Univerſe, which he is not appointed to put in Motion, his Ideas were never any thing but an odd Medley of Fancies and Uncertainties. If he ſtudies the Meaſures of Quantities and the Laws of Motions, not indeed to fathom the Heavens, or to weigh in a Balance the Maſſes of the celeſtial Bodies, but to know the Order of his Days: If he obſerves the Relations which the Aſpects of the Heaven have with regard to his Habitation, and the Progreſs of the Light through the Mediums he offers thereto; the Helps which he may find from the Equilibrium of Liquors, or from the Weight and Celerity of the Bodies he is Maſter of, or from all the other Experiments that fall under his Eye, and eſpecially under his Hand; in ſhort, if he applies Experiments to the Neceſſaries of Life, this will be a Syſtem of Phyſics full of Certainty, and productive of great Advantages. It is then theſe Subjects which I hope to make the Matter of the Converſations I ſhall hereafter prepare for you. But undertaking to determine what it is that regulates the Motion of the Univerſe, and to penetrate into the general and particular Structure of the Pieces of which it is compoſed, is renouncing the Glory of improving and making our Dominion proſper, to run after empty Hopes: It is abandoning Treaſures which lie open to us, and obſtinately knocking at a Door which has been for theſe ſix thouſand Years ſhut to us.

I

It is no conjectural Opinion, but a palpable and experimental Truth, that God gave us a very great Facility of conceiving all thoſe Things which we are to manage; and has, on the contrary, concealed from us, the Knowledge of thoſe Things which he himſelf puts in Motion, without truſting the Government of them to our Care. Thus, for Inſtance, we know not the Structure of our Stomach, becauſe God has freed us from the Care of digeſting. Let the greateſt of Anatomiſts do his utmoſt, to have the Management of his own Digeſtion; all goes very often contrary to his Intentions. On the other hand, we have in our Senſes ſo many attentive and faithful Monitors, that inform us in due time what Foods may be uſeful to us. Why then have we ſo many Means of knowing our Foods, unleſs we are charged with the Care of looking out for, and of chuſing them? And why on the contrary are we ignorant how we digeſt, if not becauſe God's Will has evidently been, that the Digeſtion ſhould be performed within us without Participation? God, by ſparing us that Trouble, ſpared us alſo the Knowledge of the Mechaniſm which conſtructs the ſeveral kinds of Fleſh or Fruit we eat, and of the Mechaniſm which extracts from them all the Juices which nouriſh us. This Knowledge would have been only fit to give us great Diſtraction. We arrive at the Age of Fourſcore without knowing what Digeſtion, or the Mechaniſm and Motion of the Muſcles are. We are ſerved without any requiſite Care of our own. Had we known the intimate Structure of the Stomach, we ſhould have had a Mind to regulate the Functions of it. God did not grant to Man this Knowledge, becauſe he made him not merely to digeſt. Digeſtion is brought about without him, and God deſigns him for other Employments. If he denies him the Knowledge of the Mechaniſm of his Stomach, for fear of multiplying his Cares, is it to be ſuppoſed that he will grant him the Knowledge of the Structure of the World, the Motions of which he did not appoint him to regulate?

I don't know whether our modern Philoſophers have rightly entered into the Plan of the Creator, when they ſet a leſs Value on the Knowledge which our Senſes procure for us, than on that which they think they derive from a profound Meditation. A ſingle Inſtance will explain what I mean.

The rough Sailor knows nothing of the Loadſtone but what his Senſes teſtify of the ſame. He knows the conſtant Direction of it towards the North; and there ends all his Learning. The Philoſopher endeavours to know the Cauſe of that Phænomenon: In order to which he employs the Pores in a ſpiral Line, the Attractions and Repulſions; and after he has for ſeveral Years together ſpent his Mechanics, Geometry, and Calculations about it, he either is forced to own that he himſelf underſtands nothing of what he ſays, or has the Mortification of not being able to make others come into his Syſtem. The ſyſtematical Philoſopher, who thinks himſelf ignorant of every thing, when he knows not the Cauſe of whatever he ſees, ſpends his whole Life in hunting after May-be's, and remains locked up in a Cloſet, where he is of no Uſe to the reſt of Mankind. The Sailor makes uſe of what his Senſes teach him of the Direction of the Load-ſtone towards the North, and with that Help goes round the World. Chuſe if you will, ten thouſand other Inſtances of effectual Knowledge, and you will find, that there are very few that are not of Uſe to us. Theſe Knowledges cannot increaſe without our becoming richer. But do we look for the Cauſes of theſe Effects? We find nothing but Unprofitableneſs and Uncertainty. Who can, after this, not diſcern the Intention of God, in the Meaſure of Knowledge, which he for the preſent grants to our Underſtanding?

It is a palpable Truth, that our whole Knowledge is only concerning particular Things. The Subjects of it are diſperſed around us, on the Earth, and in the Heavens. God, together with Eyes and Underſtanding, has endowed us with a Meaſure of Curioſity, which makes us wander from one Object to another, that new Experiments may enable us to procure our Brethren new Conveniences, and that whatever is upon the Earth, may by degrees be rendered beneficial to Mankind. But if Man can on Foot go from *Breſt* to *Pekin*, it does not follow that he will ever reach to the Moon; and though he has in his Hands ſuch a Principle of Strength, as enables him to ſuſtain in the Air whole Piles of Oak Timber, and the largeſt rough

The Motions of the Superior Planets.

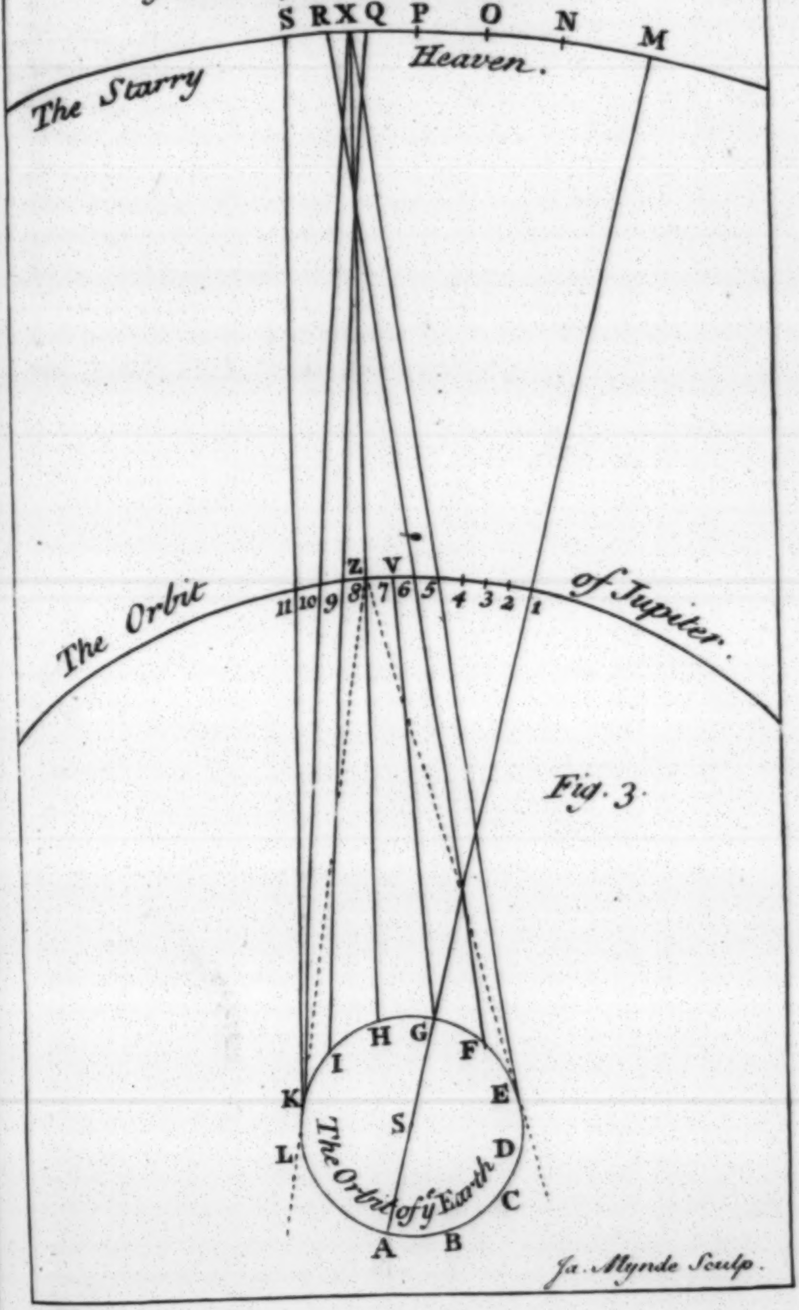

Fig. 3.

Ja. Mynde Sculp.

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Pieces of Marble; yet will he not for all that offer his Levers to the Moon, to make it jump out of its Orbit, or grapple *Mars* and the laſt of *Jupiter*'s Satellites with his Hooks, in order to procure the former the Service of one Moon, which it wants. His Knowledge is limited as well as his Strength, and theſe Bounds and his Wants are but one and the ſame thing. He is barred every where, when he ruſhes into empty Speculations: But he conſtantly goes from one Diſcovery to another, and theſe Diſcoveries produce Wonders, when he buſies himſelf about improving what is round him. Our Reaſon always employs itſelf with Succeſs, when it ſtrives to render experimental Truths uſeful to us: When it prudently makes Uſe of GOD's Favours, and praiſes him for the ſame. This is the whole Sum of Man's Knowledge.

AN EXPLICATION Of the MOTION of the PLANETS IN THE COPERNICAN HYPOTHESIS.

THERE are ſix Planets of the firſt Claſs, which turn immediately round the Sun, *viz.* *Mercury*, which makes his Revolution in three Months; *Venus*, which makes her's in ſeven Months and a half, or thereabouts; the *Earth*, which as it is much more remote, deſcribes her Orbit in 365 Days and a Quarter; then ſucceſſively, and at ſtill greater Diſtances; *Mars*, which perfects his Revolution in 686 Days; *Jupiter* in 4333, that is, in about twelve Years; and *Saturn* in 10759 Days, or in about 30 Years. There are five Planets of the ſecond Order, or which have a large Planet for the Centre of their Revolution, and are inſeparable therefrom; ſuch is the Moon with the Earth for her Centre: Such are alſo the four Stars of *Medicis*, (now the four *Satellites*) which turn at different Diſtances round *Jupiter*. Since *Galileo*'s Time five ſmall Moons have alſo been perceived revolving round *Saturn*; which make in all ten ſecondary Planets. If we were placed in the *Sun*, that is, in the fixed Centre of the Revolution of the ſix greater Planets, we ſhould ſee them revolve round us in an uniform Manner, and advancing from Weſt to Eaſt, according to the Succeſſion of the Signs. We ſhould ſee them always in their Full, that is, always turning their enlightened Half towards us. But as we ſee them from our Earth, which has a Courſe peculiar to itſelf, while they have others of their own, there thence reſults a great Variety of Effects and Situations, which introduce Inequalities, and the Appearances of Oddneſs in a Motion perfectly ſimple and uniform. Beſides, the Earth being more remote from the Sun, than *Venus* and *Mercury* are, and at the ſame time much leſs diſtant from the *Sun* than *Mars*, *Jupiter*, and *Saturn*; this Diverſity of Remoteneſs ſtill cauſes ſuch Appearances as are not the ſame in the ſuperior, as in the inferior Planets. *Mars*, *Jupiter*, and *Saturn*, are called the *Superior*, becauſe their Orbits are above ours, and incloſe it. *Mercury* and *Venus* are called the *Inferior*, becauſe the great Circle of the annual Revolution of the *Earth*, incloſes the Circle of the Revolution of *Venus*, and the Orbit of *Venus* takes in the Circle of the Revolution of *Mercury*, which is the Planet neareſt the *Sun*.

The apparent Motions of VENUS *and* MERCURY.

Their Orbits.

THE Circles which *Mercury* and *Venus* deſcribe in going from Weſt to Eaſt are not in the Plane of the Ecliptic, or of the Line which the Earth deſcribes in revolving in one Year round the Sun. But the Circles of *Mercury* and *Venus* cut the terreſtrial Orbit in two oppoſite Points, called *Nodes*, like Hoops ſet into one another, and one of which croſſes and touches the other in two Points only. The Orbit of *Mercury* makes an Angle of about ſeven Degrees with the terreſtrial Orbit; and that of *Venus* makes on each Side an Angle of three Degrees and 24 Minutes with the ſame Plane. If one ſhould ſee *Mercury* and *Venus* from the Sun, they would either be in the Line which paſſes through the Nodes and the Sun, (in which Caſe they would be ſeen in the Plane of the Ecliptic, in which the one might be eclipſed by the other) or they would be ſeen out of the Line of the Node, that is, ſometimes more, ſometimes leſs, elevated on that Plane. None of the Planets, whether primary or ſecondary, in its greateſt Elevation above that Plane, deviates from it more than ten Degrees. If therefore we take in the Heavens, a Diſtance of nine or ten Degrees on each Side the Ecliptic, we ſhall have a Breadth of 18 or 20 Degrees, to incloſe all the Declinations of the Planets. This is that large Band which we call the *Zodiac*. And the ſeveral Deviations and Re-approachings of the Planets, with regard to the Plane of the Ecliptic, are the only Variations that would be perceived in their Motions obſerved from the Globe of the Sun. But it is quite otherwiſe ſeen from the Earth. Let us remark what the Appearances of the two inferior Planets will there be.

1. *Mercury* and *Venus* muſt appear in the Plane of the terreſtrial Orbit, when they are in the Node; and theſe two Planets afterwards muſt recede from the Plane of the Ecliptic, as they deviate from the Nodes. But the Diſtance from theſe Planets to the Plane of the Ecliptic, even when they are in the ſame Part of their Circle, muſt needs appear ſometimes greater, ſometimes leſs, according as the Earth is near to, or remote from them. For it is a Law in Optics ſufficiently known, that the more remote the Eye is from the Object perceived, the ſmaller the Angle is which the ſaid Object ſeems to make with a Plane, or with another Object; and on the contrary, the nearer the Eye is, the greater is the Angle under which it ſees the Object.

2. *Mercury* and *Venus*, ſeen from the *Earth*, do not appear equally enlightened. They are ſeen with a Creſcent ſometimes increaſing, ſometimes decreaſing. They are ſeen with one whole Half ſloped off, or under the Form of a Quarter; ſometimes full, and at laſt totally darkened or eclipſed.

The two Conjunctions.

When *Mercury* and *Venus*, receding from the Earth as far as they can, get behind the Sun, and to it, as will, as to us, oppoſe their whole enlightened Half, that Situation is not called Oppoſition. This Term is reſerved to expreſs the Situation of the ſuperior Planets, when the Earth is juſt between them and the Sun. But this Paſſage of the two inferior Planets behind the Sun, is called their *ſuperior Conjunction*. It is called Conjunction, becauſe theſe Planets ſeem then to draw near the Sun, and to loſe themſelves in his Rays. It is called the ſuperior Conjunction, becauſe the Approach is made on the other Side of the Sun, and in order to diſtinguiſh it from that which is made under the Sun, when the Planet in revolving round that Star, comes and places itſelf between the Sun and the Earth. The ſecond Re-union is called the *inferior Conjunction*. The Planet in the ſuperior Conjunction is not indeed eclipſed, but drowned by the ſuperior Splendor of the Sun; and when it comes near the Line of the Nodes, it may in reality be eclipſed, by actually paſſing behind the Body of the Sun. The Planet in the inferior Conjunction ſeems again eclipſed, becauſe it is loſt in the Rays of the Sun, and becauſe it turns its whole dark Half towards us. But inſtead of being really eclipſed by the Interpoſition of ſome ſolid Body, itſelf eclipſes that Point of the Sun, over-againſt which we may perceive it by the Help of the Teleſcope. It forms a Spot which proceeds from the Eaſtern to the Weſtern Limb of the Sun. The Planet afterwards leaves it, in order to repaſs behind it, following the Succeſſion of the Signs from Weſt to Eaſt. A few Days before the ſuperior Conjunction, and ſome Days after, *Mercury* and *Venus* turn towards the Earth nearly their whole enlightened Half: They muſt of courſe be ſeen in their Full. But as they are then much more remote from the Earth, than in the Approach of their inferior Conjunction, ſince they are withdrawn from it by the greateſt Part of their Orbit, they, notwithſtanding their being at full, muſt needs appear leſs brillant, and more and more diminiſhed by the Neighbourhood of the Sun.

A few Days before the inferior Conjunction, and ſome Days after, they turn almoſt their whole darkened Half towards the Earth. We therefore muſt perceive but a very ſmall Edge of the enlightened Half, and the Creſcent muſt needs appear very dim, unleſs it begins to recede pretty much from the Sun, as it draws near the Quarter: And it is then that *Mercury* may be ſeen very well, and that *Venus* caſts a far more brillant Light than the Splendor of the full Moon. *Venus* is never brighter than when it is, not indeed in its Quadrature, that is, at 90 Degrees from its inferior Conjunction, but at 40 Degrees and little more. The Reaſon of this Difference, is, that *Venus* at 90 Degrees from her Conjunction ſeems to be nearer the Sun, and is thereby more weakened than at 40 Degrees, and ſomething more. For *Venus*, as well as any other

Planet, is perceived in the Point of the Heaven that terminates the Line which is ſuppoſed to paſs from the Earth through the Planet up to the ſtarry Heaven. Now the Line which paſſes through *Venus* at the Diſtance of 40 Degrees and a little more from the Sun, terminates at a Point of the Heaven, which appears more diſtant from the Sun than the Point where the Line drawn from the Letter T, to *Venus* in the Quadrature of her Revolution, or at 90 Degrees from her Conjunction, does terminate. For any Line that touches the Circle without cutting it, deviates more from the Extremity of the Line that croſſes the Centre, than any other Line that cuts the Circle. Now the Line drawn from the *Earth* to *Venus* being at 40 Degrees from her Conjunction, touches the Circle of the Revolution; whereas the Line drawn from the *Earth* to *Venus* in her Quadrature, or at 90 Degrees, cuts and ſlopes away the Circle. The Extremity of that Line does then begin to draw again near the Extremity of that which paſſes through the Centre, that is, near that Point of the Heaven where the Sun is ſeen. *Venus*, when ſhe is between 40 and 48 Degrees diſtant from the Sun muſt be more brillant or leſs drowned than at 90; and as ſhe leaves not the Circle of her Revolution, the Degree 40 is at the ſame time the Place where it ſhines moſt, and that at which ſhe begins to be in her greateſt Remoteneſs from the Sun. It is the ſame with *Mercury* at 30 Degrees from the inferior Conjunction. For a little after theſe Points they both begin to draw near the Sun again, in Appearance I mean, and only with regard to the Point of the Heaven under which we ſee the Sun; ſince they, in reality, always keep in an uniform Situation with regard to that Star; unleſs they, inſtead of a circular, deſcribe an oval Line round him; which however, alters nothing in our Explication, and is not the Object we muſt here employ our Thoughts upon *.

When *Mercury* and *Venus* have paſſed the ſuperior Conjunction, they from the *Earth* are ſeen advancing according to the Order of the Signs, that is, from Weſt to Eaſt. It muſt therefore thence happen, that our Horizon, turning with the Earth from Weſt to Eaſt, meets with the Sun ſooner than with theſe two Planets. They in this Caſe, therefore, ſhall riſe only after the Sun, and ſhall not be ſeen in the Morning, becauſe the Light of the Sun will drown them. But they will appear in the Evening after Sun-ſet, becauſe the Sun, being then hidden below the Horizon, they at that Time may be ſufficiently remote from him to be ſeen towards the Weſt. Therefore *Mercury* and *Venus* will be ſeen in the Evening only from the ſuperior Conjunction to the Approach of the inferior. Then it is that *Venus* is called *Heſperus*, *Veſper*, or the Evening-Star. Her Brightneſs increaſes together with her Remoteneſs from the Sun, and afterwards decreaſes in Proportion as ſhe draws near him again. It is the ſame with *Mercury*, which can hardly be perceived but at its greateſt Diſtance from the Sun, which is 30 Degrees.

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* See the Figure 1. ſubjoined.

When *Mercury* and *Venus* are near the inferior Conjunction, their Brightneſs diminiſhes. In the inferior as well as the ſuperior, they ſet and riſe with the Sun, which drowns them for ſeveral Days together. When paſſed the inferior Conjunction, they will recede from the Sun by a Motion which will appear quite contrary to that whereby they have been ſeen receding from the Sun in the ſuperior Conjunction. They at that Time went according to the Succeſſion of the Signs. Going down between the Sun and the Earth, and then receding from the Sun, they ſeem to go contrary to that Order, *viz.* from Eaſt to Weſt. By this Means becoming more Weſtward with regard to us, than the Sun, to the Right of which they at that Time are; our Horizon, by turning with the Earth from Weſt to Eaſt, ſhall meet with them ſooner than with the Sun. We therefore ſhall ſee them riſing in the Morning before Dawn, and their Elevation above our Horizon will appear greater in Proportion before the riſing of the Sun, as they ſhall be more diſtant from that Star. Then *Venus* goes by the Name of *Lucifer*, or the Morning Star. *Mercury* and *Venus* will afterwards again draw near the Sun in the ſuperior Conjunction.

A Figure will preſently make us ſenſible why *Mercury* and *Venus*, though revolving in an uniform Manner round their Orbit, yet appear to us ſometimes *direct*, or going according to the Succeſſion of the Signs; ſometimes *ſtationary*, or remaining a while in the ſame Points of the Heaven; and ſometimes *retrograde*, or going contrary to the Order of the Signs. What we are going to ſay of *Mercury*, is a ſufficient Hint of what happens alſo to *Venus*.

Their Directions, Stations, and Retrogradations.

Let the great Circle A, B, be the terreſtrial Orbit, and the ſmall Circle 1, 13. be the Orbit of *Mercury*, which may be ſuppoſed to be pretty near concentric at the Point S, that marks out the Sun, The Diſtance from *Mercury* to the *Sun*, is two fifths of that of the *Earth* from the *Sun*. The Radius of the ſmall Circle 1, 13, being to the Radius of the terreſtrial Orbit A, B, as 2 is to 5; we have the juſt Repreſentation of the Orbits of *Mercury* and the *Earth*. On the other hand, it is known that *Mercury* makes his Revolution in about three Months, and the *Earth* in twelve. Therefore the periodical Time of *Mercury* is only the fourth Part of the annual Revolution of the *Earth*,

Let us ſuppoſe *Mercury* to be in the Point of his Revolution, marked 1, and the *Earth* in the Point B; it is plain that in this Situation *Mercury*, with regard to the *Earth*, is in its ſuperior Conjunction; and if *Mercury* could then be perceived for the great Light of the Sun, we ſhould ſee this Planet in the Point of the ſtarry Heaven marked A, it being the Point to which the Obſerver muſt refer it. If on the terreſtrial Orbit you take the Ark B, S S, *viz*. the half-quarter or eighth Part of the whole, it is evident that *Mercury*, which deſcribes its entire Orbit while the *Earth* deſcribes but one quarter Part of her own, ſhall go no farther than from 1, to 13, or only make half its Revolution, whilſt the *Earth* ſhall go from B, to S S, or make one half-quarter of her Revolution. Let us divide the Ark B, S S, into 12 equal Portions, and the Semicircle 1, 13, likewiſe into 12 equal Portions. *Mercury* ſhall make one twelfth of its half Revolution, whilſt the *Earth* ſhall make one twelfth of the half-quarter of her own. Whilſt the *Earth* is going from B, to O, we ſhall ſee *Mercury* paſſing from 1, to 2, and the Eye of the Spectator ſhall ſuppoſe the Planet to go from the Point A of the ſtarry Heaven, to the Point C. Then paſſing from O to P, the *Earth* ſhall ſee the Planet *Mercury* arrive at 3, and will refer it to the Point of the Heaven D, and ſo on. The Planet in this Caſe ſhall be direct, becauſe it will appear to do what it in Reality does, *viz*. to go according to the Order of the Signs A, C, D, *&c*.

When the *Earth* ſhall deſcribe the Ark K, S S, *Mercury* going on his Part from the Point 11, to the Points 12 and 13, will appear to make only the Ark E F, whereas when the Planet was in A, it had in equal Time deſcribed the Ark A, D, much larger than E F. Of courſe it's Motion muſt then needs appear much ſlower. It is from K to S S, that it appears in it's greateſt Remoteneſs from the Sun, and the Lines drawn from the Earth to the Planet cut the leaſt of any upon the Circle of the Revolution of the Earth.

Whilſt the Earth deſcribes the Ark S S, N, T, which is equal to two Portions of another half quarter of her Orbit, and while *Mercury* deſcribes the Ark 13, 14, 15, which is two Portions of it's other half, this Planet will be ſeen with the parallel Rays S S F, N E, T G. Now it is a Rule in Optics, that when a very remote Object is ſeen by ſeveral Radii parallel among themſelves, it ſeems to be at reſt, though it be really in Motion; and it is referred to a Point of the Heaven where it ſeems to be motionleſs; becauſe thoſe parallel Radii under which it appears at ſeveral Times, though very diſtant from each other, are relative to two different Points of the Heaven, which, on account of their amazing and prodigious Remoteneſs, with Regard to us, are confounded into a ſingle one. The Planet muſt in this Caſe then appear motionleſs or ſtationary.

By this we ſee, that the Planet *Mercury* has had a direct Motion from A to E or F, and that the Time of his being direct has been much longer than that in which he was ſtationary. When afterwards the Earth ſhall deſcribe the Ark T, V, X, or four Portions of her half quarter, and *Mercury* the Ark 15, 16, or four Portions of this half, this Planet ſhall ſucceſſively be ſeen in the Points G, H, I. Now this Motion is contrary to the foregoing Direction. It will then appear retrograde, and going contrary to the Order of the Signs, or from Eaſt to Weſt. Being at the Point I, it's Swiftneſs ſhall diminiſh, and being again ſeen according to the Lines X I, Y M, which are parallel among themſelves, the Eye ſhall refer it to the ſame Point of the Heaven, the Interval of theſe two Lines vaniſhing in the Heaven, ſo that they ſeem to touch one another. *Mercury* ſhall then a ſecond time appear ſtationary. The Earth afterwards going from Y to Z, the Planet which ſhall then be in the Points 23 and 24, will in the ſtarry Heaven correſpond with the Point L, and again will begin to appear direct. It is likewiſe plain, that the Arc of Retrogradation G I, or F M, is leſs than the Arc of Direction A G or A F, and, on the contrary, that the Arc of Retrogradation is greater than that of the Station F G, or I, M.

The Motions *and* Appearances *of the Superior* PLANETS.

Fig. 3. THOUGH the ſuperior Planets, like the inferior, advance with a direct and uniform Motion in their own Orbit, yet they, as well as the Inferior have ſeveral Appearances of Irregularity, grounded on the Concurrence of the Motion and Situations of the Earth with the Aſpects of theſe Planets. The Inſtance of what is obſerved in *Jupiter*, will ſufficiently illuſtrate the Inequality of the Aſpects of the other two.

The Diſtances of *Jupiter* and the *Earth* with Regard to the Sun, are between themſelves as 26 is to 5; that is, if we conceive the Earth to be diſtant from the Sun 5 Meaſures, each of them of a certain Number of Leagues, the Diſtance of *Jupiter* from the *Sun* ſhall be 26 of the like Meaſures. If therefore you deſcribe Circumferences with ſuch Radii as may, when compared together, be between themſelves as 26 is to 5, theſe Circumferences will repreſent thoſe which the *Earth* and *Jupiter* deſcribe round the *Sun*. The *Earth* is a Year in completing her Orbit; *Jupiter* completes his in 12 Years. The twenty-fourth Part of a Circle is the half of one twelfth Part: If then we take the Ark T V, being the 24th Part of the Orbit of *Jupiter*, this Planet ſhall deſcribe the Ark T V, the Half of the twelfth Part of the whole, whilſt the *Earth* ſhall deſcribe A, B, D, G, the Half of her entire Orbit. Let us divide the Ark T V, and the Semicircle A, B, D, G, into the ſame Number of Parts reſpectively equal; for Inſtance, into 6; we ſhall be ſure that *Jupiter* will deſcribe one ſixth Part of the Portion T V, while the *Earth* deſcribes one ſixth Part of the Arc A, B, D, G. By this Means we ſhall have the principal Places where the

Earth and *Jupiter* ſhall meet together. Let us ſuppoſe the *Earth* to be in A, and *Jupiter* in Conjunction behind the Sun S in T: If *Jupiter* can at that Time be ſeen, we ſhall refer it to the Point M of the ſtarry Heaven correſponding with it. While the Earth ſhall deſcribe the Arcs A, B, C, D, *Jupiter* ſhall deſcribe 1, 2, 3, 4, and the Eye ſhall ſucceſſively perceive him in the Points M, N, O, P, of the ſtarry Heaven. The Diſtance is greater from M to N, than that from N to O, and the Arc N O is greater than the Arc O P. Therefore, tho' *Jupiter* has an equal Motion in his Orbit, we ſee him move with a Celerity which inſenſibly diminiſhes. The *Earth* going from the Point D to the Point E, *Jupiter* ſhall go from 4 to 5, and ſhall appear to proceed from P to X, a Portion of a Circle ſtill leſs than was the foregoing. It's Swiftneſs ſhall then appear to diminiſh more and more. The *Earth* afterwards ſhall deſcribe the Arc E F, and *Jupiter* 5, 6: But the Lines E 5 X and F 6 R, according to which the *Earth* ſees *Jupiter*, are parallel; therefore the Eye will refer them to the ſame Place of the Firmament, and the Planet ſhall appear motionleſs and ſtationary. If afterwards the *Earth* deſcribes the Arcs F G H I, *Jupiter* ſhall at the ſame Time deſcribe the three Arcs 6, 7, 7. 8, 8. 9. But, as the Line I 9 Q, according to which the *Earth* ſees *Jupiter*, cuts the Parallels E X, F R; the Point Q, to which the Eye refers *Jupiter* in the ſtarry Heaven, ſhall be on the Right-hand of the Points R, X, where *Jupiter* was ſeen during his being ſtationary. The Planet ſhall then appear more weſtward and retrograde. The *Earth* ſhall afterwards go from I to K, and *Jupiter* from 9 to 10, which will produce parallel Lines, and a ſecond Time make *Jupiter* ſtationary. Finally, the *Earth* paſſing from K to L, ſhall ſee *Jupiter* going from 10 to 11, and anſwering to the Point S of the ſtarry Heaven, ſo that the Planet ſhall ſeem to advance from Weſt to Eaſt, and again ſhall become direct. If we know in the ſame Manner the periodical Times of *Mars* and *Saturn*, we may by the Rule of *Kepler*, determine the Diſtances of them, and then with equal Facility expreſs their Situations. But theſe Variations are altogether inconceivable in any other Hypotheſis than that of *Copernicus*.

AN EXPLANATION Of a Few FIGURES.

THE Fontiſpiece repreſents *Galileo* making on the Tower of St *Mark*, and in Preſence of ſeveral *Venetian* Noblemen, a Trial of the Teleſcopes he had conſtructed upon the Recital of the Effects of the Spying-glaſs newly invented in *Holland*. See *il Teatro d' Huomini letterati*. Art. of *Gal.* and *Dialogue* VI. *of Part* 2. *of this Vol.*

PAGE 31.

The CREPUSCLE.

The inner Circle repreſents the Globe of the Earth. The outward repreſents the thicker Air, or the lower Region of the Atmoſphere, which encompaſſes the Earth immediately.

The Space contained between the two Circles may be called the Atmoſphere, which probably is the inferior Part of a Vortex of Æther, or of very fluid and very extenſive Matter, in which the Earth is carried away. The Vortex of the Moon revolves towards the Extremities of ours, and both, very likely, are preſſed ſometimes more, ſometimes leſs, by the Spheres of the neighbouring Planets. It will be ſufficient for the underſtanding the reſt of the Figure, to obſerve, that when the Light enters from a clearer Element, ſuch as the Æther or the pure Air, into a denſe and groſs Element, as is the groſſer Air, it bends and enters into it, inclining a ſmall Matter towards the perpendicular Line, which may be imagined from the Surface of the Fluid to the Centre. A H repreſents the Horizon with regard to the Eye placed in A.

S, The Sun at one degree under the Horizon; S, C, a Ray meeting the Atmoſphere at the Point C, and which, in entering it, is bent and deviates from it's direct Way, drawing nearer the perpendicular C T, ſo that the Ray being broken, is, by this bending, confounded with the Horizontal Line H A, and cauſes the Sun to appear to be already above the Horizon, though it is as yet under it.

S S, The Sun 18 Degrees under the Horizon. The Ray S S, E, falls upon the Atmoſphere at the Point E, and inſtead of continuing it's Way directly towards *e*, it is bent, and enters into the thicker Air a ſmall Matter. This Ray, after having been bent at E, goes directly to C, where the Horizontal Line cuts the Atmoſphere. There the Ray E C is partly loſt in the Heaven, partly reflected upon the Bottom of the Atmoſphere, and faintly brought again towards the Eye in A. The reflected Ray C A making the Angle of Reflexion B C A, equal to the Angle of Incidence E C F, this Ray muſt needs be the laſt that is viſible, ſince it grazes the Earth, and another Ray proceeding from the Sun above 18 Degrees under the Horizon, muſt needs be reflected above A, and be loſt by the Eye placed in A. The Ray S S E C A, does then mark the End of the Crepuſcle.

S S S, The Sun more than 18 Degrees under the Horizon. S S S, L, a Ray that goes and meets the Atmoſphere at the Point L. It is partly admitted therein; the reſt is reflected and loſt in the Heaven. The ſmall Part of it which enters the thicker Air at L, inſtead of going directly to *l*, is bent a ſmall Matter, grazes the Earth in I and goes to E, where it is partly loſt in the Heaven, and partly reflected from E to D C; where it becomes totally inſenſible after ſo many Diminutions, and eſpecially cannot reach the Eye in A, ſince the Angle of Reflexion D E F, being equal to the Angle of Incidence L E M, brings the remaining Part of the Ray to C, and not to A, The Light of the Crepuſcle is then inviſible, when the Sun is more than 18 Degrees under the Horizon; and this Point is the End, as well as the Beginning of the Crepuſcle.

Here we have made the Angles a great deal larger than they ſhould be, to render the Effect of them much more ſenſible in a ſmall Space. For, to reduce them to their exact Meaſure, we ought to have put the Semi-diameter A T, forty times larger than A B the Height of the Atmoſphere, which would have rendered the Figure too large in proportion to the Size of this Volume.

PAGES 191, 192.

The two Semi-planiſpheres, intitled *the firſt and ſecond Half of the Northern Celeſtial Hemiſphere*, Pag. 191, and 192, repreſent together, as in a concave Vault, the Conſtellations diſperſed in that Part of the Heaven round the arctic Pole to the Equator. Being divided, they burthen the Book much leſs, and many equally help us to follow the Order of the Stars. The other two Halves, Pag. 193 and 194, repreſent the Conſtellations of the other Hemiſphere from the Equator to the ſouthern Pole, which is the Centre of it. So ſoon as we are ſure of knowing one ſingle Conſtellation, or even a ſingle Star, as for Inſtance, the Polar, which is very near the arctic Pole, in a fine Night we may, by comparing the neighbouring Stars that are in the Planiſpheres, with thoſe we perceive in the Heavens, by degrees diſtinguiſh the latter, and call the Principal of them by their Names. As to the Origin of theſe Names and Figures, ſee the firſt Vol. of the Hiſtory of the Heaven. The Planiſpheres we here give, are drawn after thoſe of Dr. *Halley*, F. R. S.

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